AN EXPERIMENTAL ANALYSIS OF BIOFEEDBACK AND PERIPHERAL VASODILATION

A thesis
submitted in partial fulfilment
of the requirements for the Degree
of
Master of Arts in Psychology
in the
University of Canterbury

by

Christopher Michael McGeorge

University of Canterbury

1976

ACKNOWLEDGEMENTS

Thanks are due to Dr. Arreed F. Barabasz who supervised this study, to Mr. Neville M. Blampied for his support and advice, to Professor R.A.M. Gregson who assisted with the analyses, and to Mr. Geoffery I. Samuels for his part in the analyses.

CONTENTS

CONTENTS (cont.)

LIST OF TABLES AND FIGURES

ABSTRACT.

Increases in peripheral bloodflow achieved through biofeedback training, as measured by hand skin temperature, have been claimed to alleviate migraine headache conditions and Reynaud's disease. The questions of the general applicability of biofeedback techniques, the specific nature of the effects biofeedback produces, the best procedure for training the use of biofeedback, the optimum length of training required to achieve the maximum benefit, and the extent of the relationship between hand skin temperature measures and measures of blood flow, need to be elucidated before the clinical use of biofeedback can be experimentally justified.

An experiment was conducted to test the efficacy of biofeedback in training increases in the skin temperature of the hands. True auditory feedback, false auditory feedback, and relaxation instructions were administered to three randomly selected groups of psychology undergraduates. Hand skin temperature and plethysmograph measures were recorded and analysed for treatment effects by a computerised multivariate analysis of variance. The true feedback group could not be distinguished from the two control groups on the basis of treatment (ten minutes) or baseline (five minutes) measures.

It was concluded that ten minutes of biofeedback training was not sufficient to produce increases in the skin temperature of the hands, for an unselected sample of the general student population. No conclusion was possible about the relationship between temperature and plethysmograph measures, as the latter were technically imperfect.

It was recommended that potential respondees to biofeedback training be identified by means of personality, suggestibility, and locus of control tests, and that these persons be used in further research to assess the questions outlined above.

CHAPTER ONE

LITERATURE REVIEW

1.1 Introduction

This chapter discusses the literature on peripheral vasomotor experiments, and outlines the experimental hypotheses examined in the present study.

The second section deals with the research on peripheral vasomotor activity, undertaken from various orientations, but with the object of assessing this physiological response.

Section three examines evidence, largely clinical in nature, of the attempts to use peripheral vasomotor training in the treatment of migraine headaches and Reynauds disease.

The fourth section discusses studies, which point out the inherent difficulties in obtaining, and interpreting, good measures in this type of physiological research.

Section five contains a summary of the discussion, and outlines the key issues predominating in the field at present.

Section six contains the present study's intended procedures.

Section seven states the experimental hypotheses to be tested, and the experimental questions to be answered.

1.2 Research on Peripheral Vasomotor Activity

In the last decade, an increasing amount of research has been conducted into the possibility of training the bodily responses, controlled by the involuntary nervous system. Although research has been conducted on such responses as heart rate and brain wave patterns, this present study is concerned in particular, with the autonomic peripheral vasodilation response.

While classical conditioning of this response has been attempted in the past (Menzies, 1937; Shmavoman, 1959), the recent upsurge in interest has been in the operant, and in particular, the biofeedback approach, to training unelicited vasomotor activity.

The rationale of biofeedback training is that, if an organism is placed in a closed biofeedback loop and provided with information about one or more of its bodily processes, such as peripheral vasomotor activity, it can actually learn to control the specific function or functions. The method requires the application of relatively ordinary technical procedures in the measurement of pulse and/or skin temperature, and feeding back performance information to the organism. A common feedback mechanism employs a tone, which increases or decreases in frequency according to the performance of the organism.

One of the earliest research teams, claimed to have successfully instrumentally taught vasomotor learning in curarized rats (Miller and DiCara, 1968). If Miller's early work is to be believed (i.e. it has never been replicated), then the twelve rats learnt to differentially vasodilate and vasoconstrict in one ear, when reinforced for such behaviour by electrical stimulation of the median forebrain bundle. Such vasomotor learning it was claimed, was independent of heart rate, vasomotor activity in the tail, or body temperature. As Miller points out "... the results indicate that the sympathetic nervous system has a greater capacity for specific local activity than usually has been attributed to it."[(1)]. It may be judiciously pointed out, that five of this study's six references, were Miller and DiCara papers, four of which were unpublished at the time.

Snyder and Noble (1968) investigated whether or not human finger vasoconstriction, could be instrumentally conditioned in the absence of mediating skeletal responses. This was in part a replication of their 1965 study, which had not eliminated this possibility. These researchers conducted a well controlled study on a large sample (n = 54), of students, and concluded that vasoconstriction can be instrumentally conditioned, independently of gross bodily movement, muscle tension, heart rate, respiratory irregularity and minute finger movements.

It is reported in the results however, that "Continuous moderate EMG activity was found to correlate with obvious irregularity in the plethysmogram; in fact, the plethysmograph employed was more sensitive to muscle artifact than the EMG recording."[2]. It is further stated, "... large bursts of EMG activity threw the plethysmograph off scale ..."[3]. It would appear that Snyder and Noble (1968) had a very noisy trace of vasomotor activity. Despite the use of the words "obvious irregularities", it would be of interest to know how the discrimination between muscle artifact and true vasoconstriction was made.

Volow and Hein (1972) investigated bidirectional operant conditioning of peripheral vasomotor responses, using visual and auditory feedback to inform the subjects of performance success or failure. It is interesting to note, that only two of the eight subjects learned to reliably constrict, and dilate, while five achieved reliable performance in one direction only, and one subject learned neither task.

This study used monetary rewards for performance, as well as feedback, in both the auditory and visual modes. The inclusion of all these factors, may have critically loaded the task with cognitive activity, and subsequently lead to the only modest success reported. The present author found in a pilot study for this thesis, that vasomotor learning is best achieved in a very simple stimulus environment, and that such learning is militated against, by increases in the cognitive complexity of the task.

Unfortunately the report by Volow and Hein (1972) is only an abstract of a conference paper, and hence exact details of the experimental method are unavailable.

Hypnotic control of peripheral vasomotor activity was examined by Maslach, Marshall and Zimbardo (1972), by inducing subjects to achieve bilateral differences in the skin temperature of the hands. Comparatively brief testing sessions (two of ten minutes), were given with all hypnotically induced subjects producing the bilateral changes in skin temperature. Indeed, differences as much as 4°C (7.2°F)[4] appeared within two minutes of the verbal suggestion. None of the waking controls achieved such significant bilateral changes. Thermocouples attached to the forearms, showed no temperature changes at all, and thus testified to the specificity of the vasomotor response.

It should be noted however, that the hypnotic subjects had an average of ten hours hypnotic training prior to the testing and hence constitute a highly selected group.

A related study by Roberts, Kewman and MacDonald (1973), used a confounded combination of hypnosis and feedback to produce bilateral hand skin temperature changes.

Again, this experiment used selected subjects who had undergone extensive hypnotic training. Auditory feedback was provided with the hypnotic induction. Four of the six subjects produced statistically reliable changes in the correct direction, but there were marked individual differences in the rate of learning, and magnitude of control achieved. The addition of auditory feedback adds no new information, and actively confounds an otherwise modest follow-up of Maslach, Marshall and Zimbardo (1972).

Stern and Pavloski (1974) attempted to replicate Snyder and Noble (1968)'s experiment, but with the elimination of the latters' ten minute extinction period. Two separate experiments were carried out using forty-five subjects in each. The experimental design used true and partial yoking for control purposes. The subjects were not told what the required response was, but were asked to relax and watch a signal light which indicated when they were responding correctly. Results are claimed to show successful modification of the rate of vasoconstrictions, and the experimenters noted that "... the performance of the experimental groups reached almost the highest level during the very first five minute conditioning period."[5].

Because of the experimental design and numbers of subjects, and the elimination of response specific instructions, these results appear to be strong evidence that peripheral vasomotor activity can be altered by learning. In clinical terms however, the statistically significant effects reported may not be particularly useful. The difference in the mean number of vasoconstrictions, between the feedback group and the truely yoked control in the last two blocks of the twenty-five minute acquisition period were 1.2 and 1.1 respectively. Hence, while Stern and Pavloski conclude that "... vasoconstriction, an autonomic response of great relevance to hypertension and other psychosomatic diseases can be relatively easily controlled and/or conditioned ..."[(6)], they do not make explicit the result that such control amounts to a relatively small clinical effect.

Steptoe, Mathews and Johnston (1974) used earlobes in an attempt to ascertain whether precise control of peripheral blood flow can be learned. Earlobes are rich in arterivenous anastomses whose flow is controlled by sympathetic vasoconstrictor fibres. Further, earlobes provide a convenient control for the muscle artifacts which may have confounded some hand skin temperature research.

Although a significant direction x trials x sessions interaction was found, no main effects achieved significance. This is hardly surprising as the largest difference achieved between lobes was 0.26°C (0.47°F). Further, in the discussion it is noted that the temperature difference between the room and the skin, was considerably less than 24°C (43.2°F). This is the difference necessarily present before skin temperature closely follows changes in blood flow (Fetcher, Hall and Shaub, 1949). Hence the skin temperature would have been a relatively insensitive indication of blood flow in this experiment. It seems curious that while being aware of the Fetcher, Hall and Shaub (1949) findings, Steptoe, Mathews and Johnston (1974) did not take steps to ensure that at least a 24°C temperature gradient existed in the experimental chamber before running the eight subjects.

Keefe (1975) attempted to assess and overcome the confounding effects of instructional set and multiple treatment procedures, and the lack of absolute data from differential temperature training studies. During the ten minute feedback period, Keefe reports an average increase in the differential skin temperature between hand and forehead of up to 1.05°C (1.9°F), and an average decrease of up to 0.83°C (1.5°F). These differential changes correlated highly with absolute finger temperature changes ($r = 0.87$, $p < 0.01$). Keefe claims to have successfully conditioned changes in skin temperature, without the concurrent use of autogenic phrases or hypnotic suggestions.

However, the increases are not large and could have been partly due to the natural fluctuations of the subjects, and those attendent on entering an experimental situation. The pre-thesis pilot study conducted by the present author revealed that up to 5.5°C (10°F) changes in a few minutes and slow continuous change over twenty minutes may be observed in subjects given neither instructions nor feedback. Keefe's three minute baseline is therefore inadequate, as it does not establish the stability or instability of the skin temperature of the subjects.

Keefe admits the simultaneous use of feedback and response specific instructions is a criticism, but writes that further research on this question will be conducted. The small number of subjects run ($n = 8$), is a further criticism, but one that is common to the field.

Engstrom (1975) investigated the efficacy of hypnosis and biofeedback in teaching bilateral differences in skin temperature between the hands. A group of twenty-four students was selected from one hundred and two volunteers on the basis of two tests of hypnotic susceptibility. Twelve of the subjects had scored highly on the tests and twelve exhibited little or no susceptibility. Hypnosis and biofeedback training both resulted in significant increases in bilateral skin temperature, except in unsusceptible subjects given hypnosis. Engstrom concludes that hypnosis and biofeedback may be "... operationally different means to the same end...",[(7)] and if so, biofeedback would seem to have a more general application as it produced change in both susceptible and unsusceptible subjects. However, with regard to learning retention, the susceptible subjects given hypnosis appeared to retain the original levels of performance better than the biofeedback subjects.

Engstrom is open to a similar criticism to Keefe (1975), in that the biofeedback training used both response specific instructions and auditory feedback. Also, the highly selected nature of the subjects severely limits the generality of the results and may account for the success with which vasodilation was taught.

Lynch, Hama, Kohn and Miller (1976) were concerned to eliminate the effects due to respiration, skeletal muscular tension, orienting responses and habituation in the production of increases and decreases of digital temperature in six child subjects. The simple control procedure involved training differences in temperature between the hands, or between two fingers of the same hand. Both visual feedback and monetary reinforcement were provided to the four subjects of the first experiment.

Measures were taken only on the last five minutes of training and no mention is made of the temperature stability during the three minute baseline. There was no, no-treatment control. Three of the four subjects achieved statistically reliable correct responses. Examination of the graphs however, show only one subject to exhibit both a stable response and correct responses in both directions.

Two of the best subjects were given further training to produce between fingers differences. One of these made statistically significant changes, but which in absolute terms amounted to 0.22°C (0.4°F). These results are consistent with Lynch et al (1976)'s comment about previous research, which stated that, "... few individuals have been found who can reliably control vasomotor activity."(8)

1.3 Applied Uses of Peripheral Vasomotor Training

The greatest use of peripheral vasomotor training has been in the treatment of migraine headaches, although it has been tried with Reynauds syndrome. This is despite the fact McGeorge (1976a) points out with reference to migraine headaches, that "the etiological significance of finger temperature measures remains largely unknown".[9].

The most concise classification of migraine comes from the Ad Hoc Committee on Classification of Headache (1962). Migraines are "... recurrent attacks of headache, widely varied in intensity, frequency and duration. The attacks are commonly unilateral in onset; are usually associated with anorexia and sometimes, with nausea and vomiting; in some are preceeded by or associated with conspicuous sensory, motor and mood disturbances; and are often familial.

Evidence supports the view that cranial arterial distension and dilation are importantly implicated in the painful phase but cause no permanent changes in the involved vessel."[10].

The vascular behaviour in the head is related to intense sympathetic dysfunction. As vasodilation in the hands is a function of only sympathetic activation, it follows that vasodilation is a one-variable indicator of decreases in sympathetic outflow. It is a one-variable indicator, because the peripheral vasculature does not have significant parasympathetic innervation.

Thus, the aim in assisting handwarming by biofeedback is not handwarming per se. The intention is to lower sympathetic activity and as a consequence, reduce the swollen and painful cranial vasculature.

The initial work with this technique was carried out at the Menninger Foundation in Kansas. Reports of this research have appeared in several places, but the presentation of the results is poor and the work seems to be based on an informal ad hoc treatment of individual patients.

Blanchard and Young (1974) have calculated that after running some seventy-five patients, the Green Green and Walters team can only confirm some degree of clinical improvement in twenty-nine to thirty-nine per cent of the total sample. Indeed, proper evaluation of this early research is virtually impossible because little or no data are given. The treatment is of the package type and includes suggestion, relaxation and autogenic training, as well as biofeedback, while no treatment controls are not provided. Hence, no substantive conclusions on therapeutic efficacy can be drawn about the specific biofeedback component of the treatment package.

Further case reports using this technique continued to appear.

Wickramaskera (1973) reported the successful treatment of two patients by temperature training after EMG feedback training had failed to alleviate chronic headache problems.

Johnson and Turin (1975) reported success in a single subject controlled study of a migraine patient. However, the actual number of headaches during baseline was five, while the number under handwarming training was three. This suggests that additional measures may have been necessary to supplement the limited biofeedback effect.

An experimental investigation comparing temperature feedback, alpha feedback and hypnosis was conducted by Andreychuk and Skriver (1975), on thirty-three migraine sufferers. It was found that all three groups showed significant degrees of improvement between groups. A trend was discovered for the more suggestible subjects to respond more favourably to the treatment. In short, it appeared that the particular biofeedback treatments were not necessarily the relevant variables. An important finding they report, is the need to consider and account for the role of suggestibility, especially where the specificity of mediating variables (e.g. subject expectancy) is difficult to define.

Turin and Johnson (1976) attempted to test the placebo-expectancy component by training cooling in a control group of three migraine patients, while training fingerwarming in four others. No clinical improvement was apparent in the control group until fingerwarming training was given. For the warming group the mean number of headaches declined from 2.15 during the baseline period, to 1.26 at the end of training.

As with the previous Johnson and Turin (1975) study, it would appear that additional measures are needed to reduce or eliminate the high residual number of headaches. A criticism of the Turin and Johnson (1976) study is that the use of finger cooling as a control may have lead to a misleading contrast. The intention was that if cooling proved ineffective and warming proved effective in the reduction of migraine activity, and if both treatments occurred with positive therapeutic expectations, then a placebo-expectancy explanation for the positive effects of warming could be rendered untenable. Finger cooling is not however, simply the absence of fingerwarming. If the treatment model outlined on page (8) holds, then it holds for cooling as well as warming. Thus, Turin and Johnson in training finger cooling, are effectively raising sympathetic activity, and hence the likelihood of migraine activity. That is, the supposed control group are practising a migraine enhancing activity (peripheral vasoconstriction), and consequently any amelioration of the patient's condition is rendered extremely unlikely.

For these researchers to be able to claim to have eliminated suggestion, relaxation and time out effects, a truely irrelevant site should have been chosen for the control group to cool, or even warm. In this manner placebo-expectancy effects could have been controlled for.

A similar problem exists in the research conducted by Friar and Beatty (1976). A control group of nine migraine patients were trained in vasoconstriction in the hands. If training was successful, then it should have actively militated against the patients' headaches improving. That is, the headaches of this group should have become more frequent and of longer duration. Fortunately Friar and Beatty report that headache symptomatology was relatively stable in the control group.

McGeorge (1976b) treated migraine sufferers with a hand temperature biofeedback and autogenic training package. One of the hypotheses which was supported by the results, was that the training of temperature increases in the hands could be achieved within two, half hour laboratory sessions, with little or no home practise. Achievement of headache control was however very limited, and led the author to conclude that the self-regulation of somatic disturbances could not be divorced from the context of a person's life style.

Blanchard and Young (1975) report a successful treatment of a long standing case of Reynauds disease. This systematic case study shows that temperature increases of 1.1 - 1.6^{o}C (2 - 3^{o}F) were consistenly obtainable by the patient, but that several booster sessions were necessary to maintain these. Absolute hand temperatures reported in the results, indicate a gradual decrease from the 32.8^{o}C (91.1^{o}F) achieved in the early feedback training. As concurrent therapeutic practises were studiously avoided for control purposes, it would appear that supplementary assistance may have been necessary to maintain the initial improvement.

1.4 Difficulties in the Measurement of Peripheral Vasomotor Activity

One of the most common assumptions in biofeedback assisted handwarming, is that the skin temperature of the hands constitutes an adequate measure of the peripheral blood flow. Indeed the biofeedback apparatus marketed for migraine treatment is solely based on this assumption. The apparatus consists of a thermistor and dial, with a varying tone to supply feedback about temperature increases and decreases.

This assumption is however questionable. Fetcher, Hall and Shaub (1949) emphasize that skin temperature is valid as a measure of extremity blood flow under certain conditions only. From experiment, it was ascertained that a heat loss rate for the hand should be 12 kg.cal/hr., or more, if the skin temperature is to follow blood flow changes closely. This heat loss rate corresponds for example to an air insulation over the bare hand of 0.54

equivalent clo[11] (insulation units), and a temperature difference of 24°C (43.2°F) between hand and air.

The Biofeedback Technology (BFT) 301 and 302 Temperature Trainers used in the treatment of migraine headaches are hence based on a questionable rationale. Given a normal skin temperature range of 26.6 - 32.2°C (80 - 90°F), then the room temperature where the training is to take place should be no more than 2.6 - 8.2°C (36.8 - 46.8°F). As most clinical handwarming training is carried out at room temperature (i.e. 20°C or 68°F), then the efficacy of the treatment must certainly be attenuated by the misleading measures of peripheral blood flow.

Fetcher, Hall and Shaub (1949) noted that if only gross slow changes of blood flow are to be measured, correspondingly lower heat loss rates may be adequate, so that all such temperature training may not be entirely invalidated. Certainly studies claiming to show involuntary nervous system learning on the basis of fractional changes in absolute skin temperature, should be regarded with due caution if not scepticism.

It would be worthwhile to replicate the Fetcher, Hall and Shaub (1949) study with modern equipment and a number of subjects, owing to the age of the original research and its neglect to mention the number of subjects used.

Unpublished data from a study of hypnotic peripheral vasodilation training (Barabasz and McGeorge, 1976), indicate that a nonsignificant correlation ($r = 0.03$), existed between the temperature and plethysmograph measures taken from the non-dominant hand. While the technical quality of the plethysmograph measures was poor, this remains an interesting finding, because the hypnotic training significantly increased both measures over baseline levels (temperature $t = 5.5$, $p < 0.001$; pulse to $= 5.3$, $p < 0.001$). A Sign test was conducted on the Null hypothesis that the temperature and pulse measures were related only by chance. An exact probability of $p = 0.011$ was obtained for the temperature and pulse measures under

H_o, and hence H_o could be rejected at the .05 level in favour of H_1. That is, that the direction of skin temperature changes, did reflect the direction of pulse size changes.

Thus while an increase in temperature did reflect an increase in pulse size, there was no predictive relationship between the two measures concerning the magnitude of the change. However, this result needs to be verified by further research, because it could have been due to instrumentation problems.

The human thermoregulatory system's dynamic performance, holds important questions for the study of peripheral vasomotor activity. As most experimental sessions are conducted over an hour at the most, and subjects usually arrive from unspecified other activities, it is of interest to know the length of time skin temperature takes to achieve a stable state when a subject enters the experimental chamber.

Crosbie, Hardy and Fessender (1961) have performed a dynamic test on the step response on moving suddenly from essentially steady state at an ambient of 32°C (89.6°F), to one of 16°C (60.8°F). The skin temperature of the subject decreased 6°C (10.8°F) during the course of three hours, but unfortunately neither the skin area is specified, nor is the time of day tested noted.

Where the subjects are not given response specific instructions, it is of importance to know whether some of undesirable strategies (e.g. breathing and movement), experimented with by the subject, may give rise to spurious results.

The effects of increases and decreases in breathing rate, on finger pulse volume has been investigated by Engel and Chism (1967). Both ten minutes of fast paced, and ten minutes of slow paced breathing, had the effect of significantly reducing finger pulse volume over resting levels. Finger temperature also decreased monotonically from resting levels, but the decreases were only 0.2°C (0.36°F) for slow paced and 0.5°C (0.9°F) for fast paced breathing. Statistical treatment of the temperature data is not reported. These findings indicate that it is necessary to eliminate breathing, as a source of variance, if only minor changes in temperature are obtained.

Overt movement by the subject is relatively easily controlled for by observation, but Lynch, Schuri and D'Anna (1976) have demonstrated that isometric muscle tension may influence vasomotor activity. Twenty-four subjects were examined to assess the effects of static muscular contractions on peripheral vasomotor responses. Moderate exertion (with no overt bodily movement), was found to result in a significant unidirectional change in skin temperature and pulse amplitude. The actual reduction however amounted to only 0.3 - 0.4°C (0.54 - 0.72°F) over the sixty second duration of the exercise.

1.5 Literature Review Summary: Five Key Issues

The literature is in agreement, that changes in peripheral blood flow, and hence hand skin temperature, may be achieved by a person's exerting conscious control over autonomic nervous system functioning (Andreychuk and Skriver, 1975; Blanchard and Haynes, 1975; Engstrom, 1975; Green, Green and Walters, 1969; Johnson and Turin, 1975; Keefe, 1975; Lynch, Hama, Kohn and Miller, 1976; Maslach, Marshall and Zimbardo, 1972; Roberts, Kewman and MacDonald, 1973; Sargent, Walters and Green, 1973; Snyder and Noble, 1965, 1968; Steptoe, Mathews and Johnston, 1974; Stern and Pavloski, 1974; Turin and Johnson 1976; Volow and Hein, 1972; Wickramaskera, 1973).

The first issue asks the question: Do biofeedback techniques have a general application to the general human population, or are they really only effective on a certain subgroup of the general population? This question needs to be resolved before an adequate assessment can be made of the optimum method of teaching, or retraining autonomic responses with biofeedback techniques. An answer to the issue would best be achieved by replicating Stern and Pavloski (1974). That is, by attempting to apply biofeedback only, (i.e. devoid of the usual response specific instructions or autogenic phrases), to a large randomly selected sample, and comparing the results with those obtained from control groups.

The second issue concerns the elucidation of the specific effects of a biofeedback information loop. With reference to this issue Green, Green and Walters (1969) claim; "Training experiences have convinced us that for warmth control, practice at home for fifteen to twenty minutes per day during the one month training period, using autogenic-type phrases and visualizations, will enhance the efficacy of the feedback sessions in the laboratory..."[12]. Indeed such procedures as response specific instructions, relaxation instructions, autogenic phrases, hypnosis, autohypnosis and subject expectancy, have all been used, both singly and in combination, to augment the actual biofeedback principle of an information loop. Again, an assessment needs to be made of whether or not the biofeedback component of the Green, Green and Walters (1969) treatment package, could be left out, without altering the effectiveness of that treatment package. An answer to this issue could also be gained from a replication of Stern and Pavloski (1974).

The third issue concerns the assessment of the best procedure of using biofeedback techniques to retrain autonomic responses. The popular press would hold that any person given the biofeedback equipment, could best teach themselves. The surveyed literature however, suggests that a variety of procedures may produce significant changes in the activity of the peripheral vasculature, but that some are more efficacious than others. For example, minor changes were affected by Stern and Pavloski (1974), while more substantial changes were affected by Roberts, Kewman and MacDonald (1973). The former used feedback only, while the latter used feedback as well as hypnotic instruction. Thus while Stern and Pavloski (1974) did obtain statistically significant changes, it would appear that the biofeedback information loop was not as efficient when used on its own, as when it was used under the hypnotic instruction of an experimenter.

The fourth issue concerns the length of biofeedback training, required to achieve control over the autonomic responses. Green, Green and Walters (1969)'s one month training period appears to be extremely protracted, when compared to the changes produced within a few minutes reported by both Maslach, Marshall and Zimbardo (1972) and Stern and Pavloski (1974). It would appear to be in order therefore, to reduce the latter study's twenty-five minute biofeedback training period, in an attempt to assess this issue.

The fifth issue concerns the relationship between hand skin temperature measures and measures of the blood flow in the hands. Researchers using Temperature Trainers in the migraine headache field, need to know the degree of correspondence between these two measures, as well as the conditions under which the best correspondence is to be obtained. For example, it is needed to be known when the temperature measures are not adequately reflecting the peripheral blood flow changes the researchers are trying to produce.

The present research directs itself to the first, second, fourth and fifth issues delineated in this summary. That is,

-the generality with which biofeedback techniques may be effectively applied;

-the specific effects of the biofeedback information loop;

-the optimum length of biofeedback training required to produce measureable changes in the peripheral vasculature;

-and the extent of the correlation between the measures of hand skin temperature and peripheral blood flow.

1.6 Experimental Procedures

On the basis of the literature discussed above, the following procedures were determined.

(1) A sample of approximately fifty subjects would be used. The sample would not be subjected to any selection procedure.

(2) Peripheral vasodilation would be the response taught, by means of a BFT 302 Temperature Trainer.

- both hand temperature and pulse size would be recorded from the dominant hand, in order to assess whether temperature would be an adequate measure of peripheral blood flow.

(3) Response specific instructions would not be used.

(4) Only auditory feedback would be presented to the subjects, in order to keep the stimulus structure of the task as simple as possible.

(5) Control would be achieved by comparing true feedback with false feedback, and relaxation instructions. By administering each treatment to a separate group, assessment would be able to be made of specific biofeedback effects, placebo-expectancy effects and relaxation effects.

(6) An adequate baseline period would be recorded for each subject. By means of a multivariate analysis of variance, individual differences and baseline stability would be able to be assessed and adjusted for.

(8) Ten minutes of feedback training would be given, with continuous recording of temperature and pulse performance being made.

(9) A pretest questionnaire would be administered to elicit information about factors (e.g. smoking and exercise behaviour), deemed likely to affect the ability of the subjects to learn the vasodilation response.

1.7 Experimental Hypotheses and Questions

Hypotheses

(1) The three treatment groups (true feedback, false feedback and relaxation), will be discriminable on the basis of the unadjusted treatment effect measures.

(2) The three treatment groups (true feedback, false feedback and relaxation), will be discriminable on the basis of the treatment effect measures, when these have been adjusted for the individual differences found in the baseline performance and questionnaire data.

(3) With respect to the treatment effect measures, the true feedback group will register the largest changes, while the control groups (false feedback and relaxation), will register little or no change.

<u>Questions</u>

(1) To what extent are the dependent variables intercorrelated?

(2) To what extent do the questionnaire variables (e.g. sex and age), influence the treatment effect measures?

(3) Are the three treatment groups truely random samples? That is, are the three treatment groups discriminable on the basis of baseline performance, when this has been adjusted for the individual differences found in the questionnaire data?

(4) Which, if any, of the three treatments raised the skin temperature of the hands?

(5) Is the ten minute biofeedback training period sufficient to affect measureable changes in hand skin temperature and peripheral blood flow?

(6) What is the correlation between the hand skin temperature measures, and the measures of peripheral blood flow?

CHAPTER TWO

METHOD

2.1 Subjects

Introductory psychology students from the University of Canterbury, were randomly assigned to one of three treatment groups. The distribution in numbers, and sex, of the forty-nine subjects was as follows;

- falsefeedback group (FF), n = 16, males = 9, females = 7
- truefeedback group (EX), n = 17, males =10, females = 7
- relaxation group (RL), n = 16, males =12, females = 4.

2.2 Apparatus

Dominant hand blood volume was measured by a Lafeyette Pulse Pickup Crystal 76605, attached to the thumb. The responses were recorded on a Lafeyette Instrument Company, Data Graph Systems Model 77011, set at a paper speed of one millimetre per second. The deflection of the recording pen was set individually for each subject, because of the large individual differences between subjects on the recorded response.

Dominant hand skin temperature was measured by a Feedback Thermometer Model BFT 302 (Biofeedback Technology, Garden Grove, California). The Yellow Springs 700 thermistor was attached to the volar surface of the index finger. With the Temperature Trainer set in the absolute mode, on the -2.5 to +2.5 degrees Fahrenheit scale, variation in skin temperature was recorded on a Varian Model G-15-1 graph recorder. The Varian was set at a paper speed of two inches per minute, and, had a pen deflection of one inch per degree Fahrenheit.

Feedback consisted of either the Temperature Trainer generated tone, or a pre-recorded tone played on a cassette tape recorder. The tone was presented to the subjects through headphones. The relaxation instructions were pre-recorded, and were presented over headphones, to the subjects.

2.3 Procedure

All subjects were seated in a comfortable reclining chair in the temperature controlled experimental chamber. The ambient air temperature during experimentation was recorded, and was within the range $20.4^{o}C \pm 1.6^{o}$ ($68.8^{o}F \pm 3^{o}$). The feet of the subjects were elevated, level with the seat. The hands of the subjects rested on broad arm-rests.

While seated, the subjects were administered the Subject History Questionnaire (Appendix A), and then the thermistor and pulse pick-up transducer were attached. No explanation of their function was made at this stage. Once attached to the recording apparatus the subjects donned the headphones and were told to await further instructions.

A ten minute waiting period was observed from the time the subjects were seated until the preliminary treatment instructions (Appendix B) were played from a tape. At this juncture the graph recorders were initiated and a five minute baseline period ensued. The three treatments began once the baseline recording was completed.

2.4 Treatments

(1) The true feedback group (EX) received the instruction, "please commence lowering the tone now", and was played the actual tone generated by the Temperature Trainer. This tone varied according to the changes in the skin temperature of the subjects, going up in pitch when the temperature of the skin dropped, and falling in pitch when the temperature rose. Subjects received a ten minute session with the tone.

(2) The falsefeedback control group (FF), was given the instruction "please commence lowering the tone now", and was subsequently played a pre-recorded unvarying continuous tone from a cassette tape recorder. The tone, which lasted for ten minutes, was set at the same frequency as the true feedback group began with.

(3) The relaxation control group (RL), was played a tape of relaxation instructions (Appendix C), compiled

by a clinical psychologist experienced in using relaxation procedures in therapy. The tape lasted for ten minutes.

Once the treatments were completed, the subjects were disconnected from the apparatus. The experimenter then debriefed the subjects and released them from the experiment.

CHAPTER THREE

RESULTS

3.1 Introduction to the Analyses

The graph records for each subject were examined and the data was summarized in the following manner.

Each five minute period of recording constituted a sample block. Hence the baseline period constituted Block One, while the ten minute treatment period constituted Blocks Two and Three. Within each block, a temperature and a pulse figure were extracted from their respective graphs, at fifteen second intervals. Thus, for each subject, sixty temperature figures in blocks of three and sixty pulse figures in blocks of three comprised the data sample.

This basic data was reduced by computerised regression analysis to twelve figures for each subject. These twelve figures gave the intercept and slope of each block of data, which thus described the absolute temperature and pulse behaviour of the subjects as well as the rate of change of these two measures.

The F ratios derived from the regression analysis, were plotted in frequency distributions, by taking their logarithms (Appendix D). On the basis of these distributions it was decided that the pulse data were not adequately measuring the responses of the subjects to the treatments, and hence they were discarded from further analysis.

The square roots of the F ratios, from the regression analysis of the temperature data, were used to plot the equivalent t distributions[1] of Blocks One and Three. By a comparison of these distributions (Section 3.7), it could be assessed whether or not the three experimental groups, changed in skin temperature from the baseline levels.

Statistical analyses of the output of the regression analysis on the temperature data, were carried out using a multivariate analysis of variance programme (MANOVA)[2]. The flexibility of the programme made it ideal for this study because of the number of variables involved. The programme permitted unlimited re-analysis of the data on the same run, with different variables selected to be excluded, used as covariates, or used as dependent variables.

To avoid repetitious use of cumbersome names for the design factors and variables, the abbreviations employed in the computer programme are used. These are as follows:

Design Factors (Independent Variables)

EX: True feedback treatment group which received unaltered feedback from a BFT 302 Temperature Trainer.

FF: Falsefeedback treatment group which received a continuous tone from a cassette recorder.

RL: Relaxation treatment group which received relaxation instructions from a cassette recorder.

Variables (Co-variates and/or Dependent Variables

Intercept 1: The intercept from the regression analysis equation for the first (baseline) block of data.

Slope 1: The slope from the regression analysis equation for the first (baseline) block of data.

Intercept 2: The intercept from the regression analysis equation for the second block of data.

Slope 2: The slope from the regression analysis equation for the second block of data.

Intercept 3: The intercept from the regression analysis equation for the third block of data.

Slope 3: The slope from the regression analysis equation for the third block of data.

Age 1: Age of the subjects in years.

Sex 2: The sex of the subjects.

Migraine 3: Whether the subjects claimed to suffer from migraine headaches.

Strain 4: Whether the subjects perceived themselves to be under strain at their work.

Sport 5: Whether the subjects played sport regularly.

Cigarettes 6: The number of cigarettes smoked per day per subject. Pipe and cigar smokers were asked for an estimate in cigarettes, of their smoking behaviour.

Yoga 7: Whether the subjects regularly practised yoga.

Time 8: Hour of day tested.

Five different analyses of the data were undertaken. The manner in which the variables were used in the analyses is summarized in Table 1.

TABLE 1

SUMMARY OF THE ANALYSES

Analysis	Usage of the Variables		
	Excluded	Covariate	Dependent
1			Intercept 1
			Slope 1
			Intercept 2
			Slope 2
			Intercept 3
			Slope 3
			Age 1
			Sex 2
			Migr. 3
			Strain 4
			Sport 5
			Cig. 6
			Yoga 7
			Time 8
2		Intercept 1	Intercept 2
		Slope 1	Slope 2
		Age 1	Intercept 3
		Sex 2	Slope 3
		Migr. 3	
		Strain 4	
		Sport 5	
		Cig. 6	
		Yoga 7	
		Time 8	

TABLE 1 (cont.)

SUMMARY OF THE ANALYSES

Analysis	Usage of the Variables		
	Excluded	Covariate	Dependent
3	Age 1 Sex 2 Migr. 3 Strain 4 Sport 5 Cig. 6 Yoga 7 Time 8	Intercept 1 Slope 1	Intercept 2 Slope 2 Intercept 3 Slope 3
4	Intercept 1 Slope 1 Age 1 Sex 2 Migr. 3 Strain 4 Sport 5 Cig. 6 Yoga 7 Time 8		Intercept 2 Slope 2 Intercept 3 Slope 3
5	Intercept 2 Slope 2 Intercept 3 Slope 3	Age 1 Sex 2 Migr. 3 Strain 4 Sport 5 Cig. 6 Yoga 7 Time 8	Intercept 1 Slope 1

3.2 Analysis 1: Intercepts 1,2,3 and Slopes 1,2,3 and Age 1, Sex 2, Migr. 3, Strain 4, Sport 5, Cig. 6, Yoga 7 and Time 8 as Dependent Variables

This was an exploratory analysis using all variables as dependent variables in order to provide information about their means, standard deviations and intercorrelations.

The factorial design was complete with no missing cells, and an unequal number of observations (16, 17,16) per cell.

Tables 2 and 3 present the means and standard deviations for each variable concerning the main experimental hypotheses. The tabulated means indicate that there were little or no differences in temperature between the three treatment groups during the baseline period, and that this trend was not appreciably altered by the three treatments. Similarly, the rate of change of temperature, did not appreciably alter from baseline trends.

Table 4 presents the within-cells correlations of variables. There were four high positive correlations.

(1) Intercept 2 with Intercept 1 ($r = 0.968$). This indicates that there is a close relationship between the temperature in the second block, and, the temperature in the first (baseline) block, for each subject.

(2) Intercept 3 and Intercept 1 ($r = 0.916$). A close relationship between the temperature in the third block, and, the temperature in the first block is indicated thereby.

(3) Intercept 3 and Intercept 2 ($r = 0.968$). This indicates there is a close relationship between the temperature of the third block, and, the temperature of the second block, for each subject.

(4) Slope 3 and Slope 2 ($r = 0.742$). This suggests there is a close relationship between the rate of change of temperature in the third block, and, the rate of change of temperature in the second block, for each subject.

Apart from the following eight modest correlations,

TABLE TWO

ANALYSIS ONE:

MEANS AND STANDARD DEVIATIONS OF SKIN TEMPERATURE DURING BASELINE

GROUP		INTERCEPT 1	SLOPE 1
False feedback	M	86.351	0.037
	SD	7.278	0.108
True feedback	M	85.489	0.009
	SD	5.540	0.068
Relaxation	M	86.468	0.084
	SD	7.813	0.108

NB: (1) The intercept figures are Fahrenheit degrees.

(2) Intercept 1 and Slope 1 are the parameters derived from the regression analysis, of the temperature changes recorded during the five minute baseline period.

TABLE THREE
ANALYSIS ONE:
MEANS AND STANDARD DEVIATIONS OF SKIN TEMPERATURE DURING TREATMENT

GROUP		INTERCEPT 2	SLOPE 2	INTERCEPT 3	SLOPE 3
False feedback	M	87.045	0.050	88.120	0.033
	SD	7.340	0.110	6.900	0.100
True feedback	M	85.649	0.016	86.036	0.028
	SD	5.809	0.052	5.777	0.058
Relaxation	M	88.071	0.015	88.484	0.033
	SD	7.984	0.057	7.961	0.072

NB: (1) The intercept figures are Fahrenheit degrees.

(2) Intercepts 2, 3, and Slopes 2, 3, are the parameters derived from the regression analysis, of the temperature changes recorded during the treatment period. Intercept 2 and Slope 2 represent the first five minute treatment block, and the second five minute block is represented by Intercept 3 and Slope 3.

TABLE FOUR

ANALYSIS ONE:

CORRELATIONS BETWEEN VARIABLES:

WITH ALL FOURTEEN VARIABLES TREATED AS DEPENDENT

DEPENDENT VARIABLE	INTERCEPT 1	SLOPE 1	INTERCEPT 2	SLOPE 2	SLOPE 3	SEX 2
INTERCEPT 2	0.968	---	---	---	---	---
SLOPE 2	-0.303	0.386	---	---	---	---
INTERCEPT 3	0.916	0.308	0.968	---	---	---
SLOPE 3	-0.375	---	-0.305	0.742	---	---
SEX 2	---	---	---	---	0.312	---
STRAIN 4	0.328	---	---	---	---	---
YOGA 7	---	---	---	---	---	0.301

NB: (1) Only correlations greater than 0.3 and -0.3 are listed in this table.

(2) Intercepts and Slopes are measures of subject performance. 1, 2, and 3 represent the three successive five minute blocks of baseline (1), and treatment (2, 3).

(3) Sex 2, Strain 4, and Yoga 7, are variables derived from the Subject History Questionnaire.

all other correlations were low.

(5) Slope 2 with Intercept 1 ($r = -0.303$). This shows that the higher the initial (Block 1) temperature of a subject was, the lower was the rate of change achieved by that subject in the second block.

(6) Slope 3 with Intercept 1 ($r = 0.375$). This parallels (5) above, in that the higher the block 1 temperature of a subject, the lower was the rate of change of temperature achieved by that subject in block 3.

(7) Strain 4 with Intercept 1 ($r = 0.328$). This indicates that the subjects perceiving themselves to be under strain tended to be the subjects with the higher block 1 temperatures.

(8) Slope 2 with Slope 1 ($r = 0.386$). This suggests that the rates of change of temperature in the first and second blocks are modestly linked.

(9) Intercept 3 with Slope 1 ($r = 0.308$). This indicates a modestly positive link between the rate of change of temperature during the first block, and, the temperature achieved in the third block.

(10) Slope 3 with Intercept 2 ($r = -0.305$). This parallels the correlations in (5) and (6) above in that the higher the temperature in block 2, the lower was the rate of change of temperature in block 3.

(11) Sex 2 with Slope 3 ($r = 0.312$). This suggests there may be a slight sex difference on the rate of change of temperature in block 3.

(12) Yoga 7 with Sex 2 ($r = 0.301$). This indicates that one sex (female) predominates in practising yoga.

Between Groups Comparisons

This analysis, in treating all variables as dependent, did not give a significant multivariate F ratio. On the univariate F tests only Cig. 6 achieved significance ($F = 3.943$, $DF = 2, 46$; $p < 0.026$). This result is trivial however, as it could have been predicted a priori, because of the evident differences in smoking behaviour between groups as shown by the Subject History Questionnaire.

Slope 1 was the only variable to approach significance on the univariate F tests ($F = 2.531$, $DF = 2, 46$; $p < 0.091$).

3.3 Analysis 2: Intercepts 2,3 and Slopes 2,3 as Dependent Variables; Intercept 1, Slope 1, Age 1, Sex 2, Migr. 3, Strain 4, Sport 5, Cig. 6, Yoga 7, and Time 8 as Covariates

This analysis was undertaken to assess whether the groups could be discriminated on the basis of treatment effects, when the latter were adjusted for the block 1 performance and the eight questionnaire variables.

Test of Dependent Variables and Covariates Relationship

The within-cells regression of the dependent variables on the covariates in this analysis was significant on one dimension for the multivariate F test ($F = 25.692$, $DFHYP = 40$, $DFERR = 126.988$, $p < 0.001$; $R = 1$). This significance indicates that the dependent variables and the covariates were significantly related, and hence the adjustments made to the dependent variables removed a significant amount of covariance error.

Between Groups Comparisons

The groups were not discriminated in this analysis on the multivariate or univariate F tests at the $p < 0.05$ level. This result suggests that by using Intercept 1 and Slope 1, together with the eight questionnaire variables as covariates, the error variance due to individual differences is removed and hence any hypothesised treatment effect is dissipated. Removing error due to individual differences in this way is a statistically more sophisticated equivalent of matching.

3.4 Analysis 3: Intercepts 2,3 and Slopes 2,3 as Dependent Variables; Intercept 1 and Slope 1 as Covariates; Age 1, Sex 2 Migr. 3, Strain 4, Sport 5, Cig. 6, Yoga 7 and Time 8 excluded

This analysis was run to test the idea that the within-cells regression significance obtained in Analysis 2, was due only to the fact that Intercept 1 and Slope 1 were included as covariates and not due to any influence from the eight questionnaire variables.

Test of Dependent Variables and Covariates Relationship

The within-cells regression of the dependent variables on the covariates in this analysis was significant in two dimensions on the multivariate F test, ($F = 380.329$, $DFHYP = 8$, $DFERR = 82$, $p < 0.001$; $R = 1$) and ($F = 3.852$, $DFHYP = 3$, $DFERR = 41$, $p < 0.016$; $R = 0.467$). This indicates that a significant amount of covariance error was removed by adjusting the dependent variables for the two covariates. As evidenced by the high R values there is a close relationship between these two sets of variables. It is thus confirmed that the eight questionnaire variables did not contribute to significance of Analysis 2.

Between Groups Comparisons

The groups were not discriminated in this analysis on the multivariate or the univariate F tests at the $p < 0.05$ level. This result confirms that of Analysis 2 in that once individual differences have been adjusted for, there is no discernable treatment effect when using Intercepts 2,3 and Slopes 2,3 as dependent variables.

3.5 Analysis 4: Intercepts 2,3 and Slopes 2,3 as Dependent Variables; Intercept 1, Slope 1, Age 1, Sex 2, Migr. 3, Strain 4, Sport 5, Cig. 6, Yoga 7 and Time 8 excluded

To complement Analyses 2 and 3, Intercept 1 and Slope 1 were excluded along with the eight questionnaire variables, to assess whether treatment effects might appear if the four dependent variables used in the two analyses were unadjusted for individual differences. It was felt that less sophisticated statistical techniques not allowing adjustment for individual differences may have lead early researchers in this field to report false positive results, and hence, this possibility was explored in Analysis 4.

Between Groups Comparisons

The groups failed to be discriminated by the dependent variables. Neither multivariate not univariate F tests achieved significance at the $p < 0.05$ level.

These results, taken together with those of Analyses 2 and 3, demonstrate most clearly that the three experimental groups could not be in any way discriminated on the basis of the treatments they received.

3.6 Analysis 5: Intercept 1 and Slope 1 as Dependent Variables; Age 1, Sex 2, Migr. 3, Strain 4, Sport 5, Cig. 6, Yoga 7 and Time 8 as Covariates; Intercepts 2,3 and Slopes 2,3 excluded

This analysis was undertaken finally to assess whether the groups could be discriminated on the basis of their block 1 (baseline) performance, when this had been adjusted for the eight questionnaire variables. As such it constituted a test of the randomness of subject selection.

Test of Dependent Variables and Covariates Relationship

The within-cells regression of the dependent variables on the eight questionnaire covariates did not achieve significance at the $p < 0.05$ level on either the multivariate or univariate F tests. This indicates that dependent variables and covariates were not related and hence no significant amount of covariance error was removed by adjusting the dependent variables.

Between Groups Comparisons

The groups failed to be discriminated by the dependent variables on either the multivariate or univariate F tests at the $p < 0.05$ level. As a check then, this analysis confirms the randomness of the subject selection procedure and strengthens the comments the experimental design has produced about the three treatments.

3.7 Regression Analysis $F^{\frac{1}{2}}$ Distributions

To assess experimental question five (i.e. did each group change from baseline levels), the F statistic from the Regression Analysis of the temperature data was used.

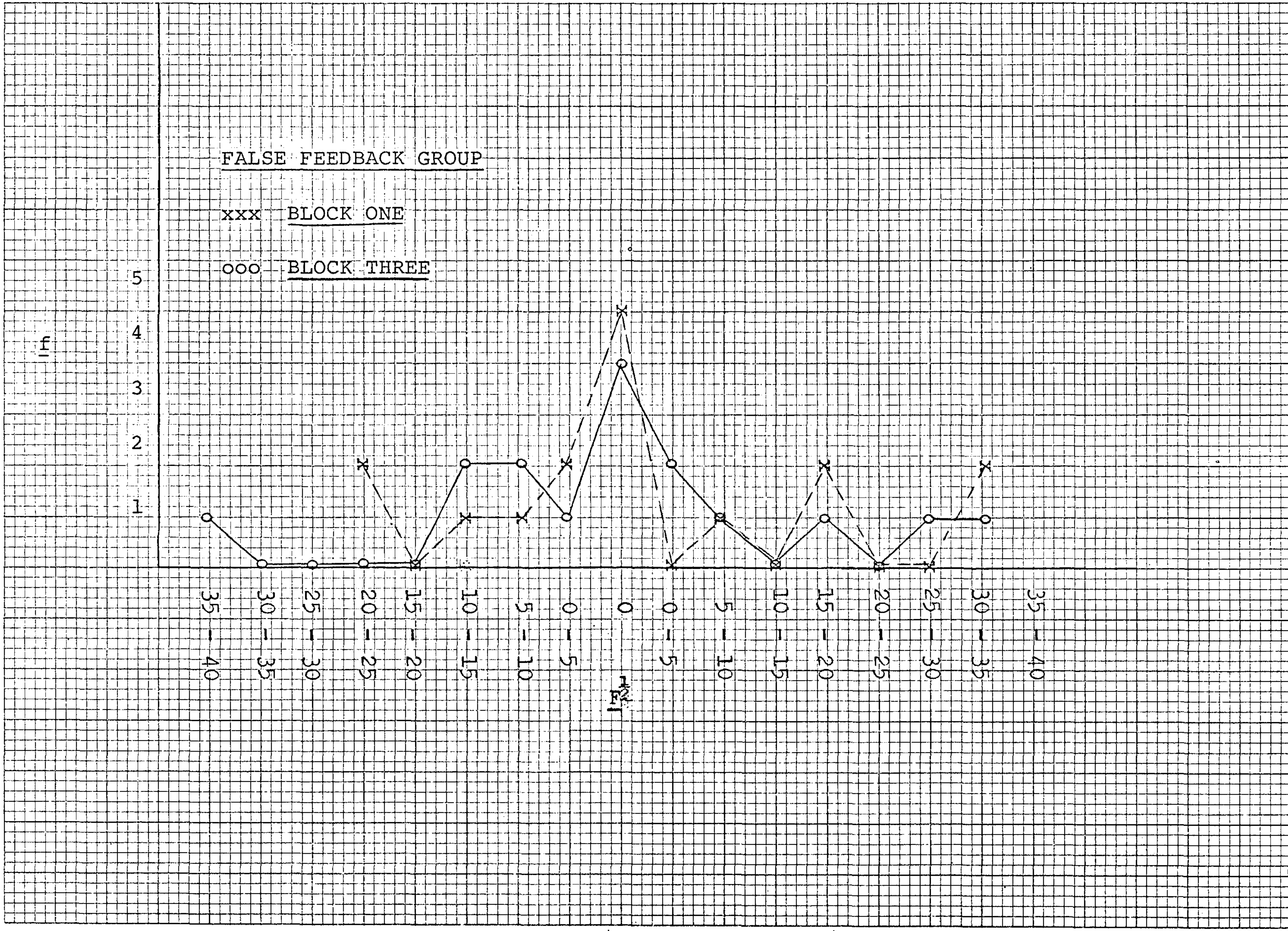
By comparing Block One (baseline), with Block Three (end of treatment), answers could be given to this question.

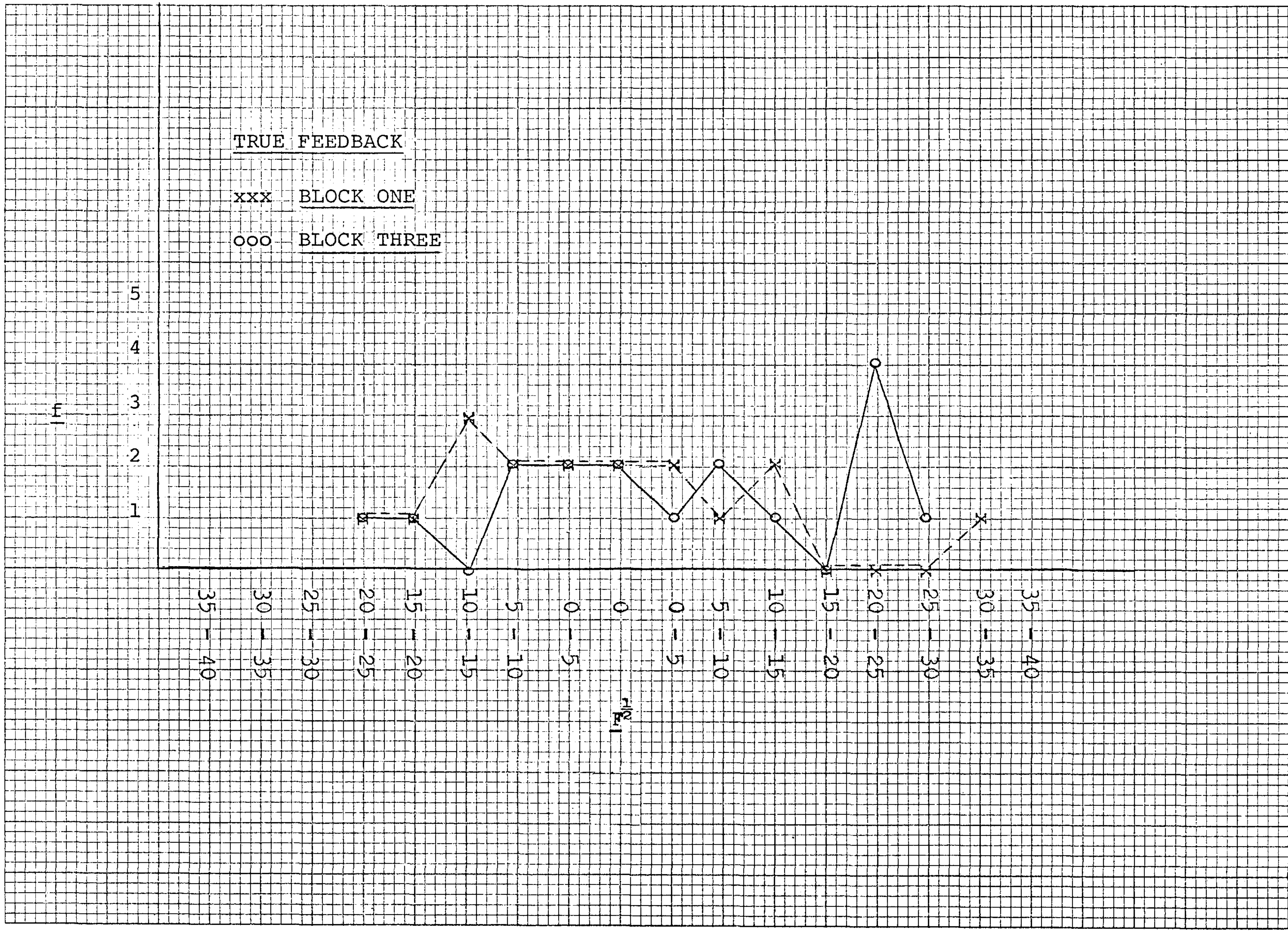
The square root of the F statistic is similarly distributed to the Student t distribution. The derived t values were assigned the sign value of the slope, to which they referred. Thus the Null Hypothesis stated that the distributions of Block One and Block Three, should both have a mean of zero and the Standard Deviation of the t distribution for 18 degrees of freedom. (The Regression Equations were based on 20 observations).

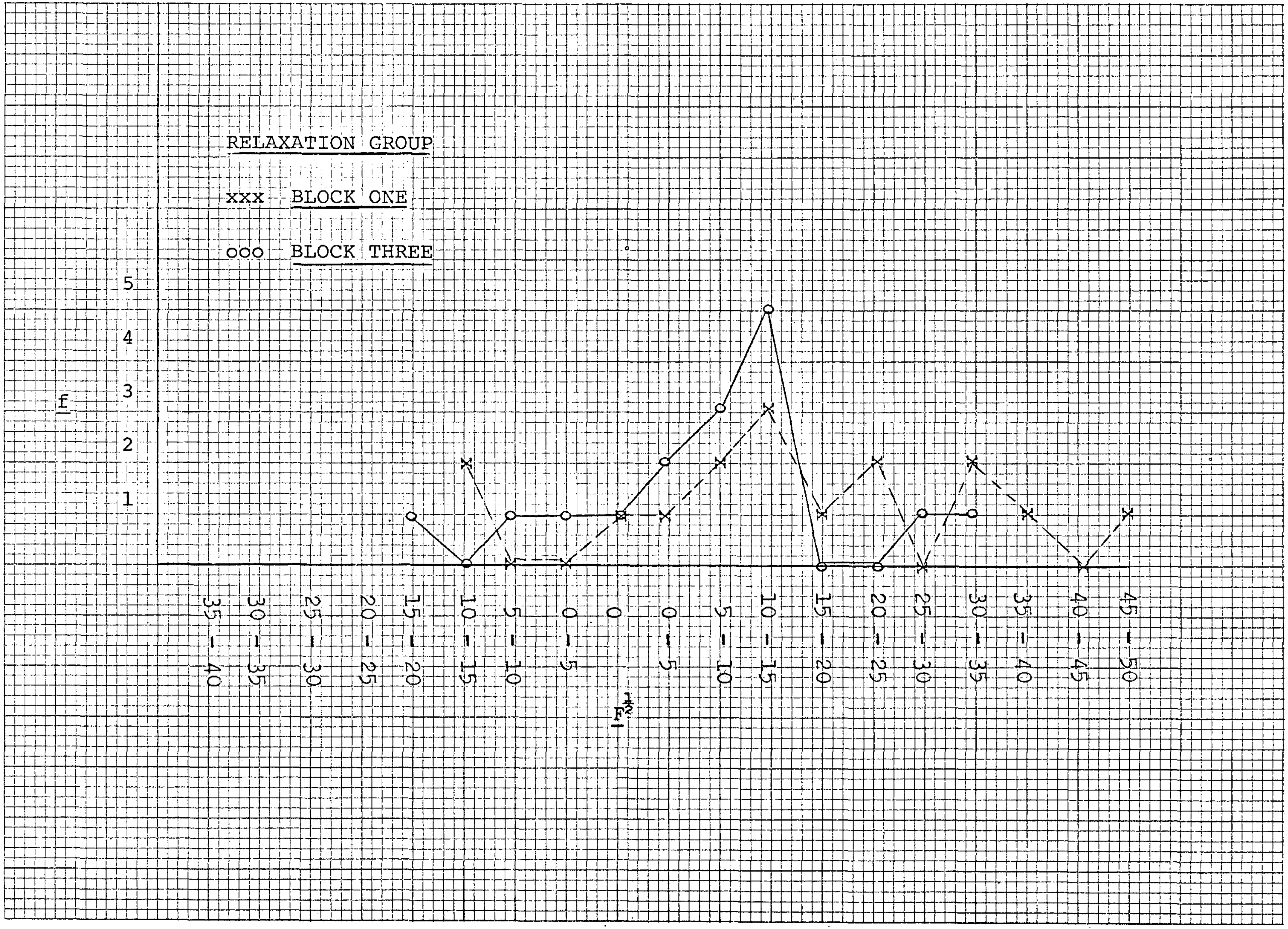
Graphs of the three experimental groups t distributions appear overleaf.

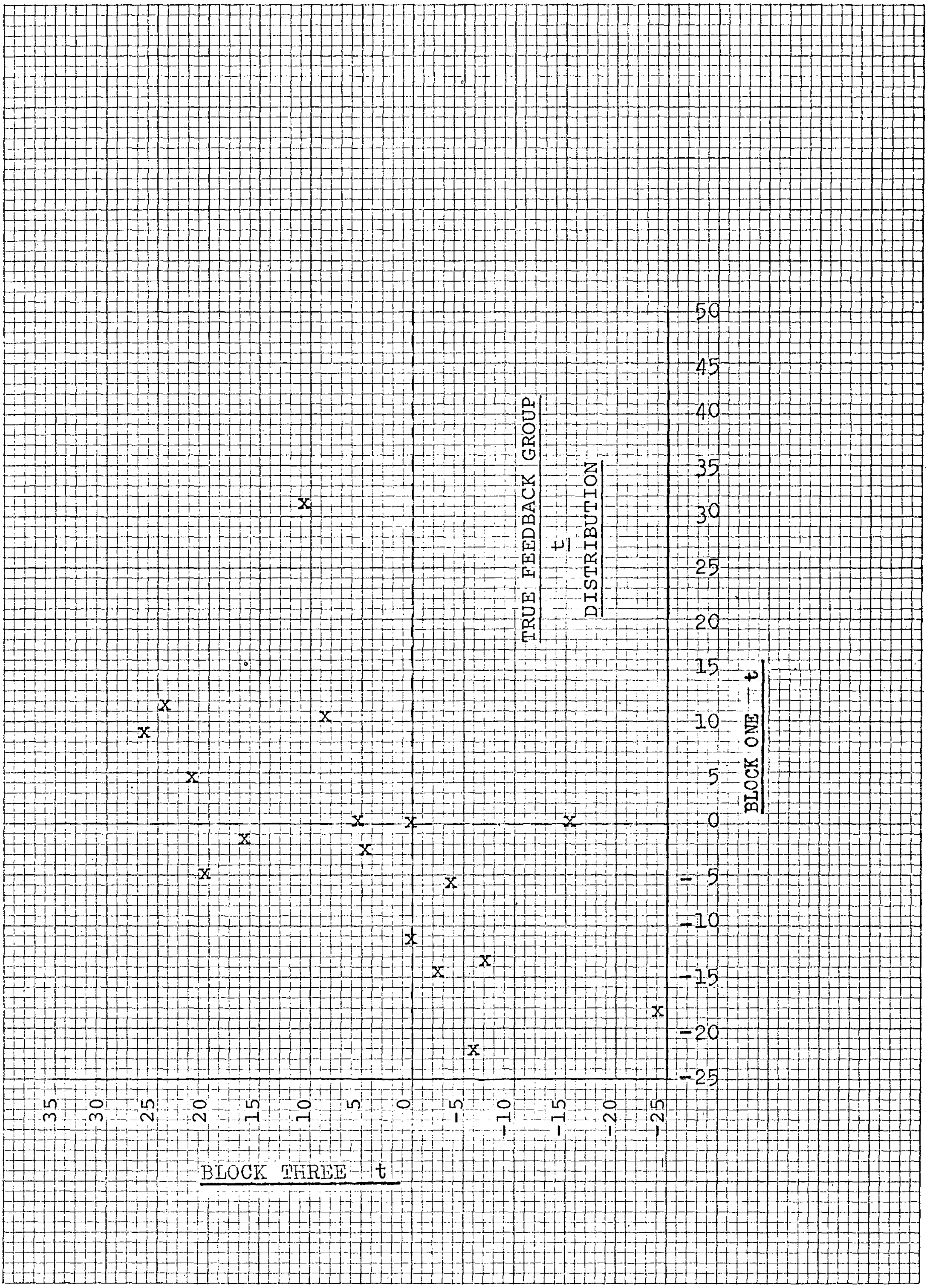
It may be seen that the falsefeedback, or control group, follows the t distribution closely enough for the Null Hypothesis to be accepted. The 95% credible intervals for $\bar{t}$, confirms that Blocks One and Three have very similar distributions for this group (Block One, $-38.03 \leqslant \bar{t} \leqslant 38.95$; Block Three, $-21.77 \leqslant \bar{t} \leqslant 27.03$).

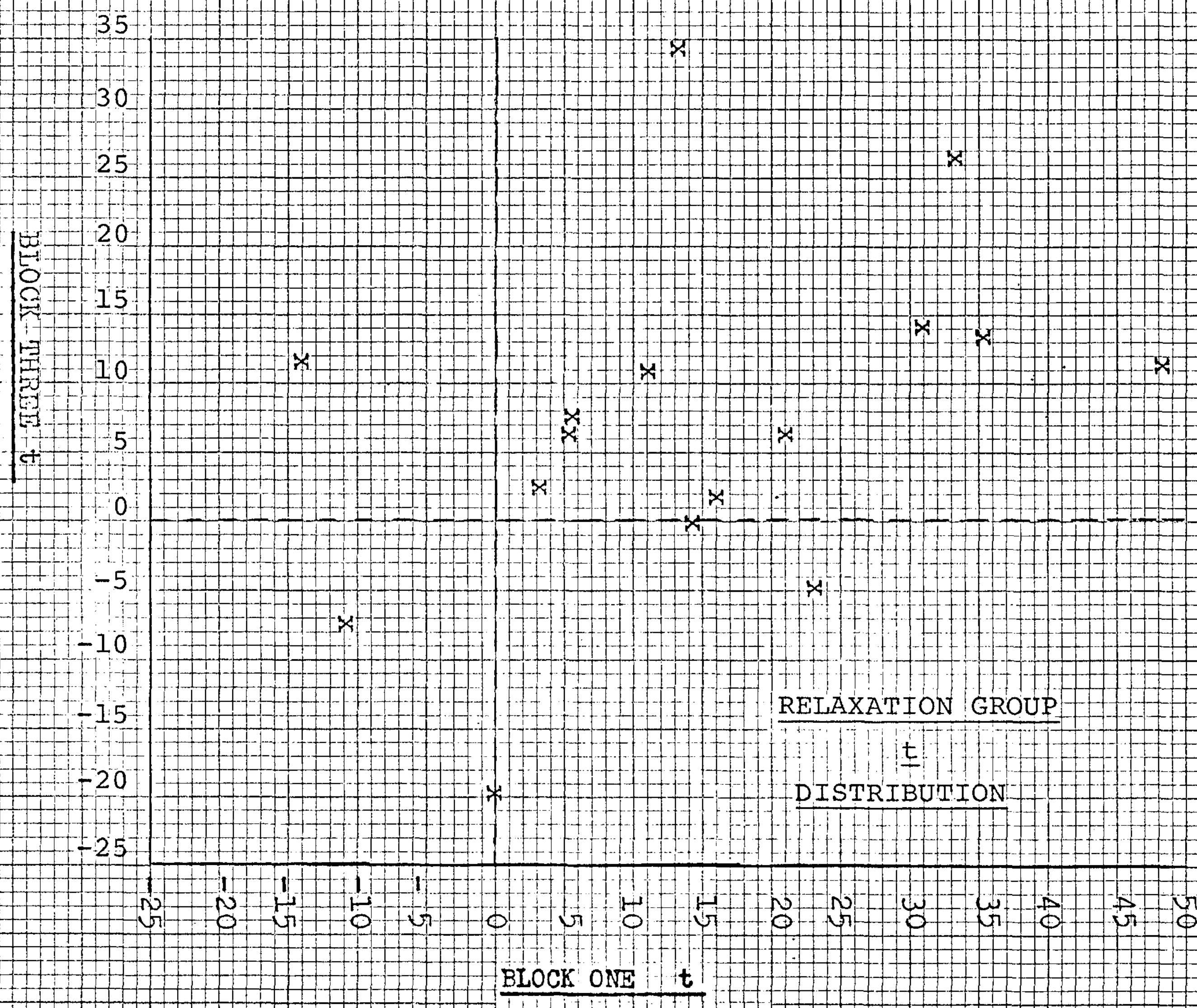
The truefeedback group exhibits some differences in trend between Block One and Block Three. These were further examined by plotting Block One against Block Three, in the graph on page (39). This bivariate plot shows that


FALSE FEEDBACK GROUP
xxx BLOCK ONE
ooo BLOCK THREE
f
5
4
3
2
1
35 – 40
30 – 35
25 – 30
20 – 25
15 – 20
10 – 15
5 – 10
0 – 5
0
0 – 5
5 – 10
10 – 15
15 – 20
20 – 25
25 – 30
30 – 35
35 – 40


TRUE FEEDBACK
xxx BLOCK ONE
ooo BLOCK THREE
f
5
4
3
2
1
35 – 40
30 – 35
25 – 30
20 – 25
15 – 20
10 – 15
5 – 10
0 – 5
0
0 – 5
5 – 10
10 – 15
15 – 20
20 – 25
25 – 30
30 – 35
35 – 40


RELAXATION GROUP
xxx BLOCK ONE
ooo BLOCK THREE
f
5
4
3
2
1
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
0 - 5
0
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
$\bar{F}$


TRUE FEEDBACK GROUP
t DISTRIBUTION
BLOCK ONE t
BLOCK THREE t


RELAXATION GROUP
t
DISTRIBUTION
BLOCK THREE t
BLOCK ONE t
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50

treatment had little or no effect on the skin temperature behaviour. Those subjects exhibiting decreases in Block One continued to do so in Block Three, and similarly, subjects exhibiting increases in temperature in Block One continued to do so in Block Three. The virtual absence of data points in the (- +) quadrant, and the complete absence of data points in the (+ -) quadrant, shows that treatment did not alter the already existing temperature trends.

The relaxation group shows a positively skewed distribution, indicating that there was a tendency for subjects to be rising in temperature in Block One. Again a bivariate plot (page 40) revealed that treatment had little or no effect on temperature trends. With the exception of two subjects, those who increased in temperature in Block One, also increased in Block Three, and those who decreased in Block One, maintained a similar trend in Block Three.

The large tails of the $F^{\frac{1}{2}}$ distributions for the truefeedback and relaxation groups, indicate that possible treatment effects may be dwarfed by the high within groups variance. This suggests that much more is needed to be known, both about the natural fluctuation of skin temperature in the hands, and the individual differences in that fluctuation, before adequate assessment of treatments purporting to influence skin temperature, can be achieved.

CHAPTER FOUR

DISCUSSION

4.1 Experimental Hypotheses

(1) The results of Analysis 4 clearly indicate that a discrimination between the three treatment groups on the basis of unadjusted temperature measures, cannot be achieved.

(2) The results of Analysis 2 clearly indicate that when the temperature measures are adjusted for individual differences during baseline performance, the treatment groups remain undiscriminated.

(3) By implication of the above two findings, and the examination of the $F^{\frac{1}{2}}$ distributions, the true feedback group did not register the largest temperature change.

Consequently for each of the experimental hypotheses, the Null Hypothesis must be accepted. This study has therefore failed to replicate the findings of Stern and Pavloski (1974). There are several possible reasons for this result. An examination of these reasons, follows in the next section.

4.2 Implications of Accepting the Null Hypothesis

The questionnaire and baseline performance data, could have revealed that the groups were discriminable before the three treatments were administered. Thus the effect of the treatments in this case would have been to reduce the between groups variance. This possibility was eliminated by Analysis 5, which revealed that the composition of the groups prior to treatment was not discriminable. That is, the randomness of subject selection was confirmed.

The possibility existed that the biofeedback training would not raise hand skin temperatures above the levels maintained by the two control groups. As the $F^{\frac{1}{2}}$ distributions revealed, this possibility eventuated. That is, because the biofeedback training did not significantly alter hand skin temperatures, the three groups which could not be discriminated by the baseline measures, continued to be indiscriminable by the measures of the treatment effects. This finding leads to a consideration of the biofeedback treatment effectiveness.

It would appear that one, ten minute training session of biofeedback, was not sufficient to affect significant changes in hand skin temperature, by altering the peripheral bloodflow. However, this finding really depends on the extent of the relationship between the skin temperature measures and the measures of peripheral blood flow. It may have been the case that the peripheral blood flow was slightly altered by the biofeedback training, but that the temperature measures were insensitive to such change under the experimental conditions existing at the time. Unfortunately, this question remains unanswered by the present study, owing to the poor quality of the plethysmograph measures.

There is a second possibility in that such biofeedback training may only be effective for a subgroup of the population, so that while some subjects did increase hand skin temperatures, this limited effect was masked by the results being averaged over the whole group. This conjecture cannot be answered by the present study and warrants further research.

The fact remains however that the biofeedback treatment did not significantly increase hand skin temperatures.

4.3 Conclusions

In terms of the issues outlined in the literature review summary (1.5), the following conclusions may be made.

While specifically biofeedback effects were not generally evident, some individuals did increase hand skin temperatures under this treatment. This finding agrees with the comment made by Lynch, Hama, Kohn and Miller (1976) that, "... few individuals have been found who can reliably control vasomotor activity."[1]. This conclusion is not in agreement with Stern and Pavloski (1974)'s finding, of a general ability to consciously alter autonomic nervous system activity.

Linked to this issue, is the question of the optimum length of biofeedback training required to achieve significant changes in the peripheral vasculature. It is concluded that one, ten minute session is not sufficient for an unselected group of the general student population. Therefore Stern and Pavloski (1974)'s finding that the greatest effect of biofeedback training can be achieved within five minutes, cannot be confirmed. The present study used instructions identical with those used by Stern and Pavloski (1974), but examined vasodilation instead of vasoconstriction. It may be the case that vasoconstriction is more amenable to biofeedback training than vasodilation. Further research to delineate the possibly differential effects biofeedback training has on vasoconstriction and vasodilation is warranted.

The exact nature of the effects of biofeedback training remain unelucidated. It is concluded that the questions of the generality of application and optimum length of training need to be resolved before the issue of biofeedback's specific effects can itself be resolved.

No conclusion is possible about the extent of the relationship between hand skin temperature measures and measures of peripheral blood flow.

4.4 Suggestions for Further Research

A primary need exists for basic parametric data on hand skin temperature and peripheral blood flow in resting subjects. This study used a five minute baseline recording period, but it is apparent that this is not sufficient when possible treatment effects may amount to less than the within subjects variance. Hence more data is needed on the natural fluctuations in hand skin temperature when the body is subjected to varying ambient air temperatures.

Further information about the generality of biofeedback's application to the general population is required. This could be gained by running more subjects through the true feedback condition outlined in the treatment Section 2.4. In doing so, an attempt should be made to distinguish subjects responding to the treatment from those who fail to respond to it. This could be attempted by using personality, and suggestibility tests, together with Rotter's Locus of Control test. If a discrimination could be made of those who would respond to biofeedback treatment before the administration of such treatment, a move could be made to prevent biofeedback techniques from being used as a panacea for the ills of the world, and thereby falling into general disrepute.

Stemming from the generality of application issue, is the question of the elucidation of the exact nature of the specific effects biofeedback training results in. This could best be examined with selected responsive subjects. It is unlikely that a general replication of Stern and Pavloski (1974), or the present study, would be an appropriate answer to this question, as the specific effects would again be masked by the behaviour of subjects remaining unresponsive to biofeedback training.

Finally, more data is needed on the relationship between skin temperature and plethysmograph measures, in order to establish the conditions under which hand skin temperature is an adequate measure of peripheral blood flow.

4.5 Summary

True feedback, false feedback and relaxation instructions were administered to three randomly selected groups of psychology undergraduates, in an experiment to test the efficacy of biofeedback, in training increases in the skin temperature of the hands.

Hand skin temperature measures were recorded and analysed for treatment effects. The true feedback group could not be distinguished from the two control groups. It was concluded that the ten minute training period was not sufficient to produce increases in the skin temperature of the hands, for an unselected sample of the general student population. Two subsidary conclusions raised the questions that biofeedback training may only be applicable to a certain as yet unspecified subsection of the general population, and that hand skin temperature may not be an adequate measure of changes in peripheral blood flow under some conditions.

It was recommended that potential respondees to biofeedback training be identified by means of personality, suggestibility and locus of control tests, and that these persons be used in further research to assess the optimum length of biofeedback training, the specific effects of biofeedback training, the pattern of natural fluctuations in skin temperature, and the appropriateness of skin temperature as a measure of peripheral blood flow.

NOTES

Chapter I

(1) DiCara, L.V. and Miller, N.E. Instrumental Learning of vasomotor responses by rats: Learning to respond differentially in the two ears. Science, 1968, 159, p.1486.

(2) Snyder, C. and Noble, M. Operant conditioning of vasoconstriction. Journal of Experimental Psychology, 1968, 77, p.267.

(3) Ibid.

(4) The present study used experimental equipment calibrated with the Fahrenheit scale, but as the literature was divided in the use of Fahrenheit and Centigrade measures, the author considered the presentation of both scales to be appropriate. Conversion was affected by the following formulae;

$$\frac{(x^{o}F - 32)}{1.8} = y^{o}C$$

and $$(y^{o}C \times 1.8) + 32 = x^{o}F \ .$$

(5) Stern, R.M. and Pavloski, R.P. Operant conditioning of vasoconstriction: A verification. Journal of Experimental Psychology, 1974, 102, p.331.

(6) Ibid. p.332.

(7) Engstrom, D. Hypnosis versus biofeedback among hypnotisable and unhypnotisable subjects. In G.E. Schwartz and T. Shapiro (Eds.), Consciousness and self-regulation: Advances in research. Volume 1. New York: Plenum, 1975.

(8) Lynch, W.C., Hama, H., Kohn, S., and Miller, N.E. Instrumental control of peripheral vasomotor responses in children. Psychophysiology, 1976, 13, p.219.

(9) McGeorge, C.M. Biofeedback and the headache. The New Zealand Psychologist, 1976, 5, p.24.

(10) Ad Hoc Committee on Classification of Headache. Classification of headache. Journal of the American Medical Association, 1962, 179, p.717.

(11) These units are defined in an article, "A practical System of Units for the description of the heat exchange of man with his environment".

Gagge, A.P., Burton, A.C., and Bazett, H.C. Science, 1941, 94, 428. One clo is described as the amount of insulation necessary to maintain in comfort, a subject resting in a sitting position in a normally ventilated room (air movement 20 ft/min or 10 cm/sec) at a temperature of 70°F (21°C) and a humidity of less than 50%. The clo equation is not strictly applicable to a portion of the body, having been derived for the body as a whole, and equivalent clo has been used. There is no equivalent S1 unit to clo and the system is therefore obsolete.

(12) Green, E.E., Green, E.E., and Walters, E.D. Self-regulation of internal states. In J. Rose (Ed.), Progress of cybernetics: Proceeding of the International Congress of Cybernetics. London: Gordon and Breach, 1969, p.1311.

Chapter III

(1) The square root of the Fratios are distributed approximately in the shape of a t distribution. Because both distributions are grouped about a mean of zero and have equivalent standard deviations, useful comparisons can be made between the two, concerning the possible deviations from the norm exhibited by the $F^{\frac{1}{2}}$ distribution.

(2) Devised by Dr. Elliot Cramer at the University of North Carolina and modified by Professor R.A.M. Gregson to run on the Burroughs computer at the University of Canterbury.

Chapter IV

(1) Ibid.

REFERENCES

Ad Hoc Committee on Classification of Headache. Classification of headache. Journal of the American Medical Association, 1962, 179, 717-718.

Andreychuk, T. and Skriver, C. Hypnosis and biofeedback in the treatment of migraine headache. The International Journal of Clinical and Experimental Hypnosis, 1975, 23, 172-183.

Barabasz, A.F., and McGeorge, C.M. Biofeedback, hypnosis and peripheral vasodilation. Hypnosis Quarterly. (In press).

Blanchard, E.B. and Young, L.D. Clinical applications of biofeedback training - a review of evidence. Archives of General Psychiatry, 1974, 30, 573-590.

Blanchard, E.B. and Haynes, M.R. Biofeedback treatment of a case of Raynaud's disease. Journal of Behaviour Therapy and Experimental Psychiatry, 1975, 6, 230-234.

Crosbie, E.J., Hardy, J.D., and Fessenden, E. Electrical analog simulation of temperature regulation in man. IRE Trans. Bio-Medical Electronics, BME 8(4) (Oct., 1961).

DiCara, L.V. and Miller, N.E. Instrumental learning of vasomotor responses by rats: Learning to respond differentially in the two ears. Science, 1968, 159, 1485-1486.

Engel, B.T. and Chism, R.A. Effect of increases and decreases in breathing rate on heart rate and finger pulse volume. Psychophysiology, 1967, 4, 83-89.

Engstrom, D. Hypnosis versus biofeedback among hypnotisable and unhypnotisable subjects. In G.E. Schwartz and T. Shapiro (Eds.), Consciousness and self-regulation: Advances in research. Volume 1. New York: Plenum, 1975.

Fetcher, E.S., Hall, Jr., J.F., and Shaub, H.G. The skin temperature of an extremity as a measure of its blood flow. Science, 1949, 110, 422-423.

Friar, L.R. and Beatty, J. Migraine: Management by trained control of vasoconstriction. Journal of Consulting and Clinical Psychology, 1976, 44, 46-53.

Green, E.E., Green, E.E., and Walters, E.D. Self-regulation of internal states. In J. Rose (Ed.), Progress of cybernetics: Proceeding of the International Congress of Cybernetics. London: Gordon and Breach, 1969, 1299-1317.

Johnson, W.G. and Turin, A. Biofeedback treatment of migraine headache. A systematic case study. Behaviour Therapy, 1975, 6, 394-397.

Keefe, F.J. Conditioning changes in differential skin temperature. Perception and Motor Skills, 1975, 40, 282-288.

Lynch, W.C., Hama, H., Kohn, S., and Miller, N.E. Instrumental control of peripheral vasomotor responses in children. Psychophysiology, 1976, 13, 219-221.

Lynch, W.C., Schuri, U. and D'Anna, J. Effects of isometric muscle tension on vasomotor activity and heart rate. Psychophysiology, 1976, 13, 222-230.

McGeorge, C.M. Biofeedback and the headache. The New Zealand Psychologist, 1976, 5, 16-25.

Maslach, C., Marshall, G., and Zimbardo, P.G. Hypnotic control of peripheral skin temperature: A case report. Psychophysiology, 1972, 9, 600-605.

Menzies, R. Conditioned vasomotor responses in human subjects. Journal of Psychology, 1937, 4, 75-120.

Roberts, A.H., Kewman, D.G., and MacDonald, H. Voluntary control of skin temperature: Unilateral changes using hypnosis and feedback. Journal of Abnormal Psychology, 1973, 82, 163-168.

Sargent, J.D., Walters, E.D., and Green, E.E. Psychosomatic self-regulation of migraine headaches. In L. Birk (Ed.), Biofeedback: Behavioural medicine. New York: Grune and Stratton, 1973.

Shamavoman, B.M. Methodological study of vasomotor conditioning in human subjects. Journal of Comparative and Physiological Psychology, 1959, 52, 315-321.

Snyder, C. and Noble M. Operant conditioning of vasoconstriction. Paper presented at the meeting of the Midwestern Psychological Association, Chicago, April 1965.

Snyder, C. and Noble, M. Operant conditioning of vasoconstriction. Journal of Experimental Psychology, 1968, 77, 263-268.

Steptoe, A., Mathews, A., and Johnston, D. The learned control of differential temperature in the human earlobes: Preliminary study. Biological Psychology, 1974, 1, 237-242.

Stern, R.M. and Pavloski, R.P. Operant conditioning of vasoconstriction: A verification. Journal of Experimental Psychology, 1974, 102, 330-332.

Turin, A. and Johnson, W.G. Biofeedback therapy for migraine headaches. Archives of General Psychiatry, 1976, 33, 517-519.

Volow, M.R. and Hein, P.L. Bidirectional operant conditioning of peripheral vasomotor responses with augmented feedback and prolonged training. Psychophysiology, 1972, 9, 271.

Wickramaskera, I.E. Temperature feedback for the control of migraine. Journal of Behaviour Therapy and Experimental Psychiatry, 1973, 4, 343-345.

Reference Note

McGeorge, C.M. Biofeedback handwarming therapy for migraine headaches. Journal of Behaviour Therapy and Clinical Psychiatry. Submitted. 1976.

McGeorge, C.M. An exploratory investigation of biofeedback and peripheral vasodilation. (Unpublished Pilot Study). 1976.

APPENDICES

APPENDIX A

SUBJECT HISTORY QUESTIONNAIRE

NAME: ______________________ AGE: ________

SEX: ____________

(Please tick the appropriate option)

(1) Do you suffer from Migraine or severe headaches?
YES: ________ NO: ________

(2) Does any member of your family suffer from Migraine?
YES: ________ NO: ________

(3) If you answered YES to Question One, is the pain felt on one side of the head only?
YES: ________ NO: ________

(4) If you answered YES to Question One, in your headache attack do you;
Feel sick ________ Feel giddy ________ Vomit ______
Is your eyesight affected ________ Other __________

(5) Are you under strain at your work or study?
Never ________ Constantly ________ Occasionally _____

(6) What sport(s) do you play regularly? ________________

(7) Do you practise Transcendental Meditation?
YES: ________ NO: ________

(8) On average, how many cigarettes do you smoke a day?
None ________; 0-5 ________; 5-10 ________;
10-20 ________; Over 20 ________

(9) Do you practise yoga?
YES: ________ NO: ________

APPENDIX B

Instructions for True Feedback and False Feedback Groups

This is an experiment in learning. I shall show you how to develop a physiological response over which you have no direct control.

All you have to do is to listen to the tone coming from these headphones and try to lower the sound in pitch. (An example of this).

While you are doing this, just sit in a comfortable position, relax, breathe quietly and evenly and do not make any unnecessary movements.

This procedure will take about twenty minutes, so if you get uncomfortable and have to move, go ahead and change position, but do not keep moving round any longer than is necessary. It is necessary for you to stay awake. If any of the equipment slips or you become uncomfortable you can tell me as I will be just around the corner, but please maintain silence otherwise.

You will be told exactly what this experiment is about after this recording period.

You will be told when to commence lowering the tone.

(A five minute baseline period ensued).

Please commence lowering the tone now.

Instructions to Relaxation Group

In today's procedure you will learn how to develop deep relaxation throughout your entire body.

Research has shown us, that in developing this type of relaxation, muscle groups ease, all over the body. In so doing the blood circulation improves greatly in the extremities such as the fingers.

The improved blood flow, that goes along with the relaxation results in comfortable increases in skin temperature that we can measure.

The relaxation instructions will follow after just a short interval.

(A five minute baseline period ensued).

APPENDIX C

Relaxation Instructions

All you have to do, is to listen to my instructions carefully and just do exactly what I tell you to do. The procedure will take about ten minutes, so if you get uncomfortable and have to move, go ahead and change position, but do not keep moving round any longer than necessary. It is necessary for you to stay awake. If any of the equipment slips or you become uncomfortable, you can tell me as I will be just around the corner, but please maintain silence otherwise. You will be told exactly what this experiment is about after the recording period.

Begin by getting as comfortable as you can, settle back comfortably, just try to let go of all the tension in your body. Now take in a deep breath, breathe right in and hold it and now exhale, let the air out quite automatically and feel a calmer feeling beginning to develop.

Just carry on breathing normally and just concentrate on feeling heavy all over in a very pleasant way. Study your own body's heaviness. This should give you a calm and reassuring feeling, a calm and reassuring feeling all over.

Now let us work on tension and relaxation contrasts. Try to tense every muscle in your body, just tense every muscle. Your jaws, tighten your eyes, your shoulder muscles, your arms, chest, back, stomach and legs. Every part just tensing and tensing. Feel the tension along all over your body, tighter and tighter, tensing everywhere, and now let go. Just stop tensing and relax, try to feel this wave of calm that comes over you as you ease up and let go, just easing up, a definite wave of calm now, becoming more and more deeply relaxed all over, more and more deeply relaxed all over, greater and greater degrees of relaxation going throughout your entire body.

I want you to notice the contrast between the slight tensions that are there when your eyes are open and the disappearance of these surface tensions as you close your eyes. So while relaxing with the rest of your body, just open your eyes and feel the surface tensions that will disappear when you close your eyes. Now close your eyes and feel the greater degree of relaxation with your eyes closed.

All right, let us get back to breathing, keep your eyes closed and take in a deep, deep breath and hold it. Keep the rest of your body as relaxed as possible, as you notice the tension holding your breath. Study the tension, and now let out your breath and feel the deepening relaxation. Just go beautifully relaxing now, breathe normally and just feel the relaxation flowing into your forehead, scalp and right out to the very tips of your fingers. Think of each part as I call it out, just relaxing, letting go, easing up, becoming comfortably warmer, eyes relaxed, nose relaxed, facial muscles relaxed, fingers becoming more relaxed and easing up. You might feel a tingling sensation as the relaxation flows in. You might well begin to notice a warm sensation, whatever you feel, I want you to notice it and enjoy it to the full, as the relaxation now spreads very beautifully to the face, the lips, jaws, tongue, mouth, so that your lips are slightly parted, jaw muscles relax further, and further, the throat and neck relaxing, the shoulders and arms relaxing. Relaxing more and more, right out to the tips of your fingers. Feel the relaxation flowing into your arms, flowing to the very, very tips of your fingers, relaxation flowing through, becoming more and more deeply relaxed all the time, more and more comfortably relaxed and warm.

Feel the relaxation in your chest as you breathe regularly and easily, the relaxation spreads even under your armpits and down your sides, right into the stomach area. The relaxation becomes more and more obvious as you do nothing, but just give way to the pleasant serene emotions which fill you as you let go. More and more deeply relaxed, more deeply relaxed all the time, a comfortable relaxation going through your body in a warm penetrating waving calm down your hips, buttocks, thighs, and to the very, very tips of your fingers and toes. The waves of relaxation just travel down your calves to your ankles. Feel relaxed from head to toe, from shoulder to fingertip.

Each time you practise this, you should find a deeper level of relaxation being achieved. A deeper serenity and calm. A good calm feeling.

Now to increase the feelings of relaxation at this point, I want you to just keep on relaxing, and each time you exhale, each time you breathe out for the next minute, I want you to think the word relax to yourself. Just think the word relax as you breathe out. Now just do that for the next minute, thinking the word relax, and letting the relaxation and warmth spread to the very, very tips of your toes and fingers. Go ahead now.

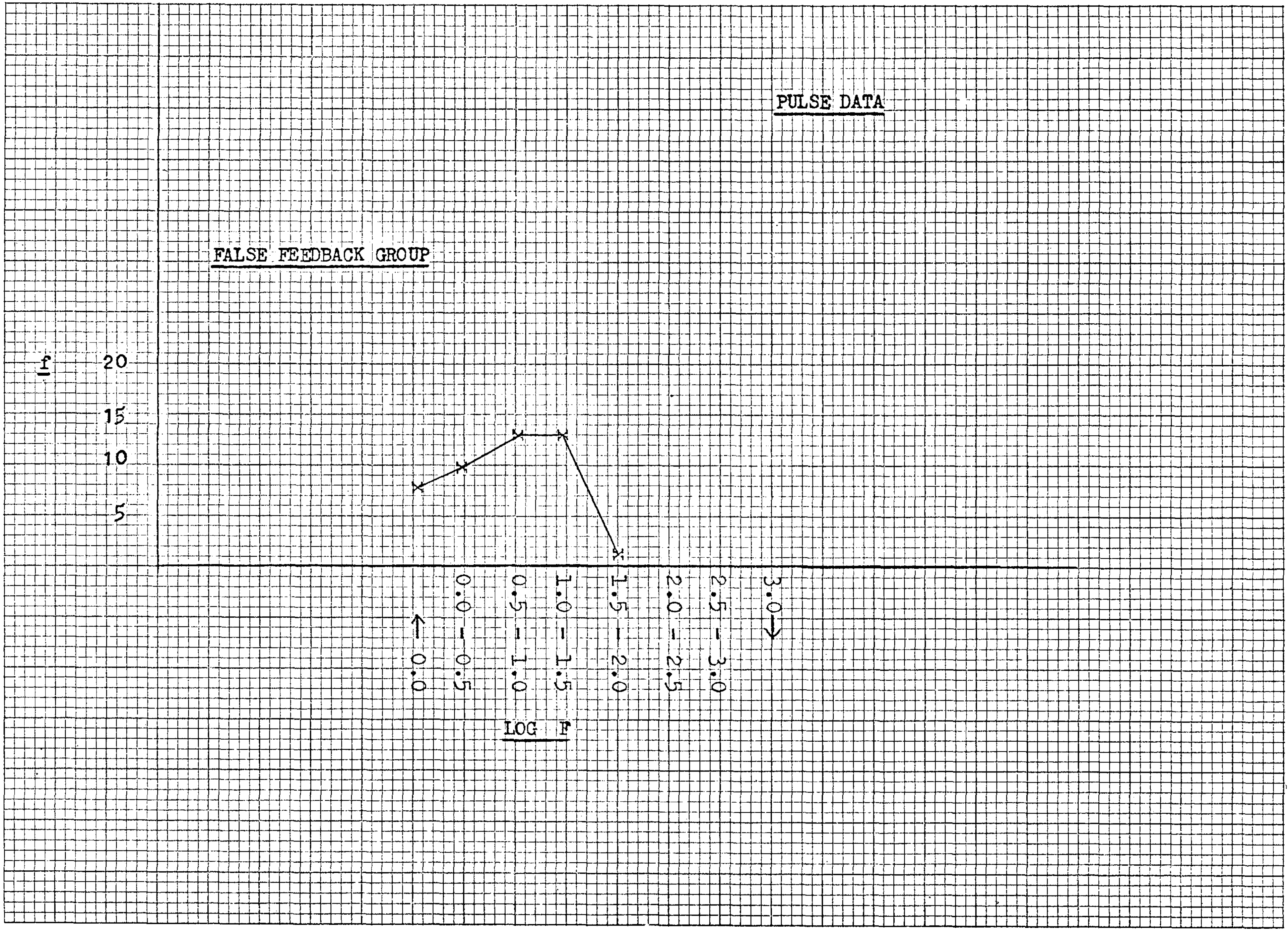
(One minute break).

O.K., just feel that deeper relaxation and carry on relaxing. You should feel a deeper, and deeper feeling of relaxation. To even further increase these benefits, I want you to feel the emotional warm calm, those tranquil and tranquil and serene feelings, which tend to cover you all over, inside and out, right out to the very tips of your toes and fingers. A feeling of safe security, a calm indifference. These are the feelings which relaxation will let you arrive at, a feeling of inner confidence, a good feeling about yourself. Now once more feel the heavy sensations that accompany relaxation, as your muscles switch off, so that you have a good contact with your environment. Nicely together, the heavy good feeling of feeling yourself comfortably warm, calm, secure and very, very tranquil and serene, to the very, very tips of your fingers and toes.

I am going to count backwards now, from ten to one. When I reach five, I would like you to open your eyes and when I reach one, I would like you to sit up once again. You should then feel refreshed and very, very calm all over.

Ten, nine, eight, seven, six, five, open your eyes now, four, three, two and one. Wide awake, refreshed and calm.

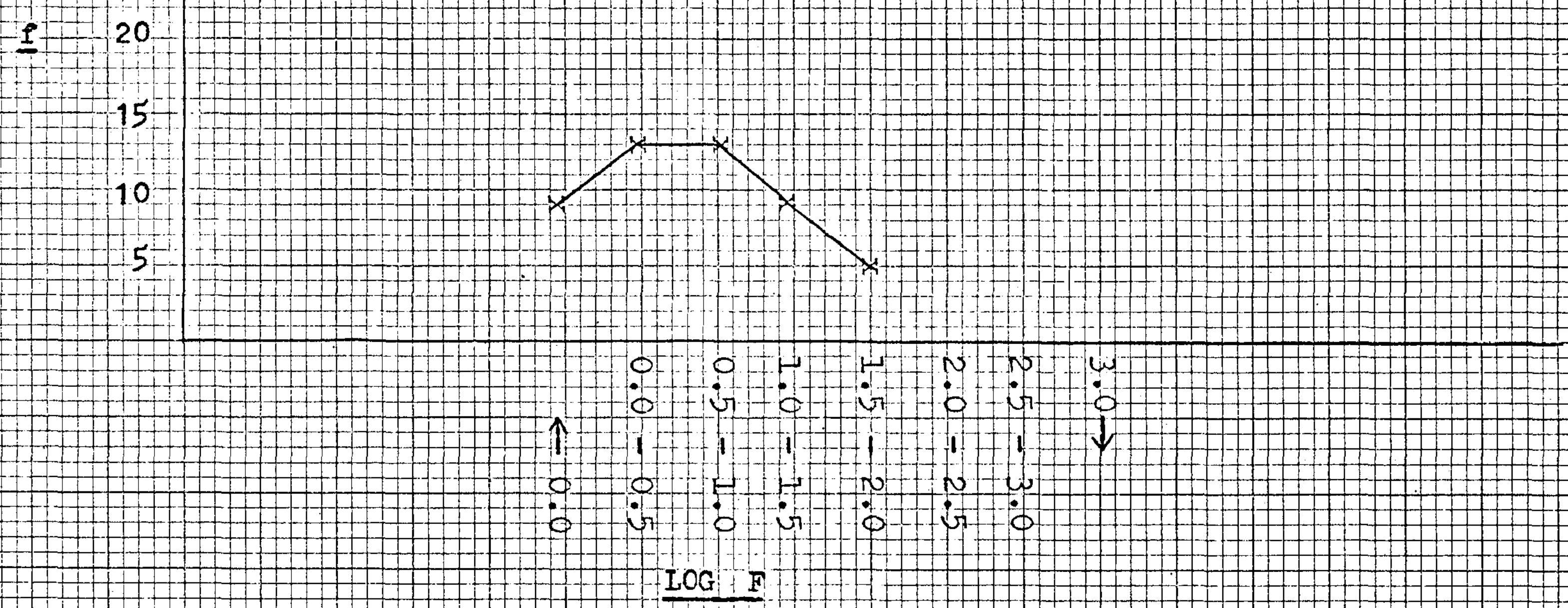
APPENDIX D

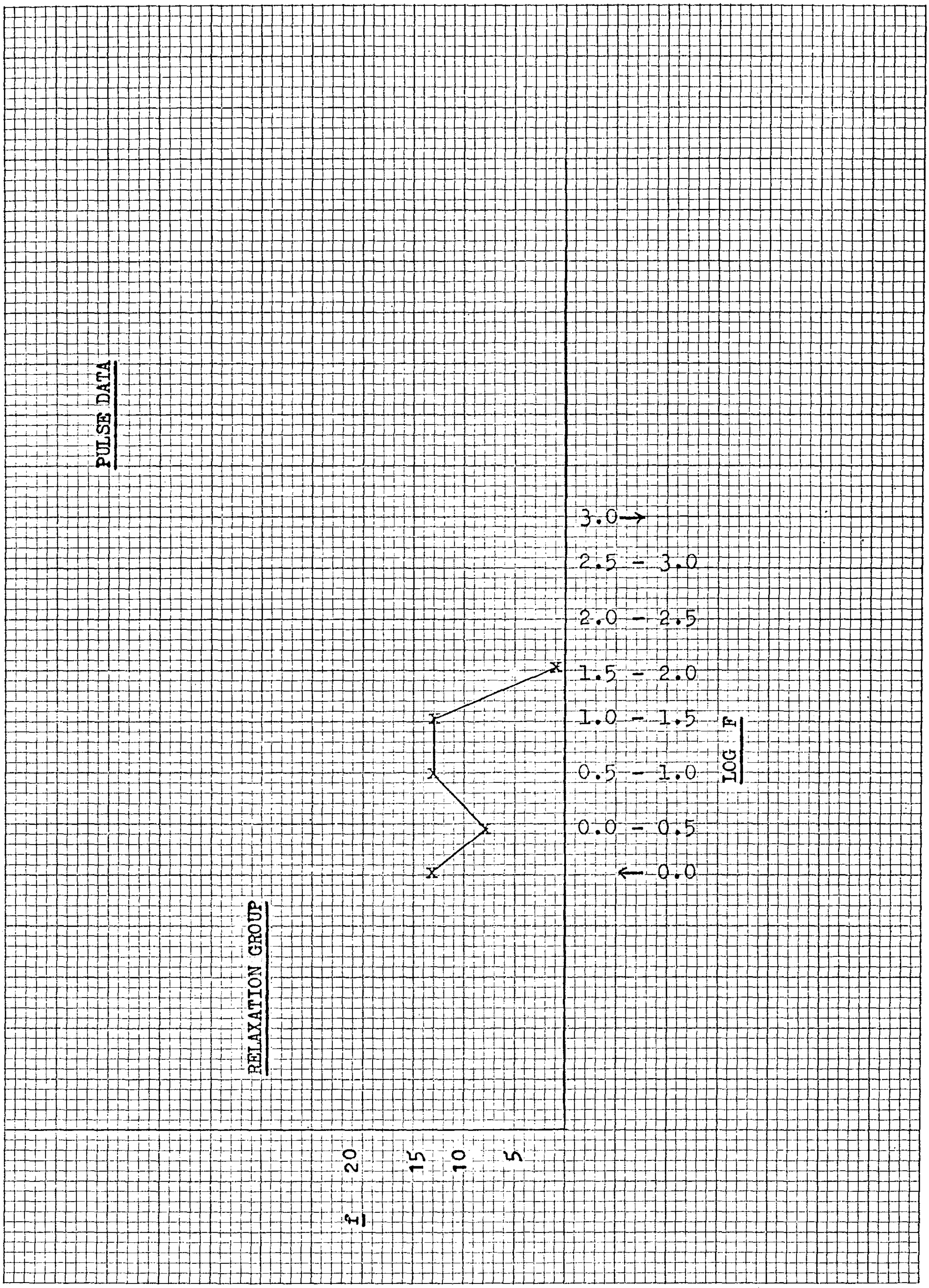


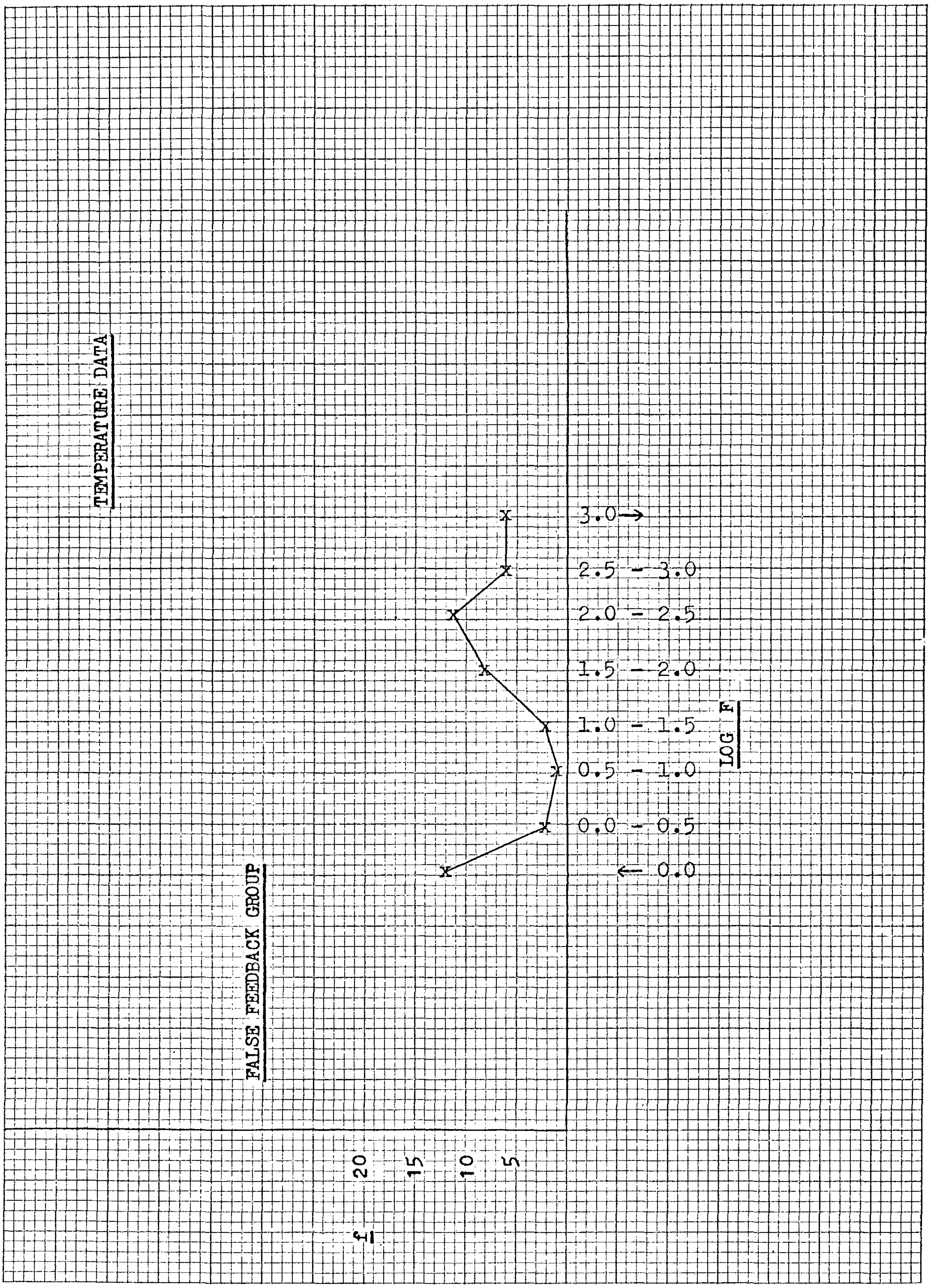
PULSE DATA
FALSE FEEDBACK GROUP
f
20
15
10
5
← 0.0
0.0 – 0.5
0.5 – 1.0
1.0 – 1.5
1.5 – 2.0
2.0 – 2.5
2.5 – 3.0
3.0 →
LOG F

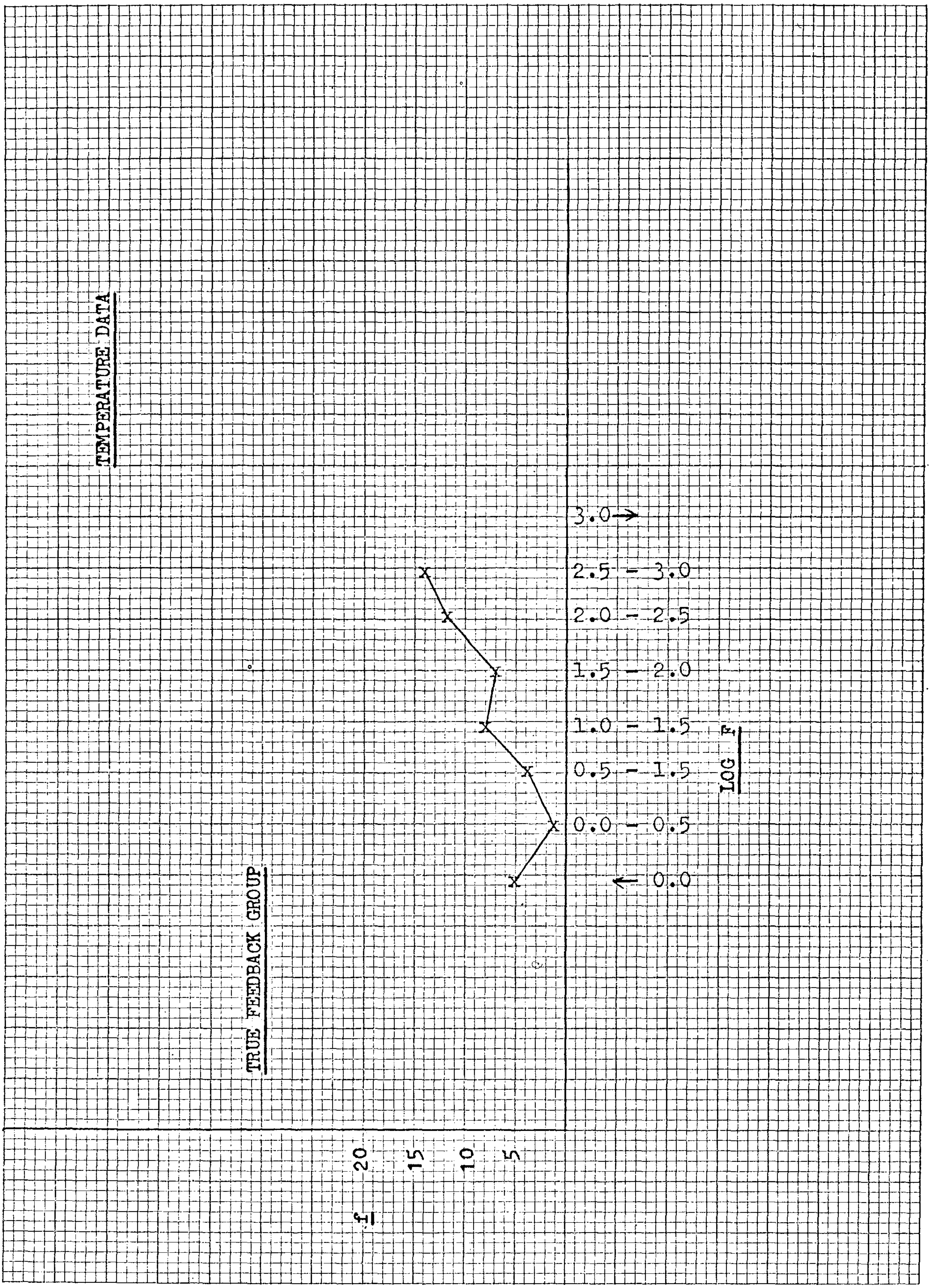
PULSE DATA

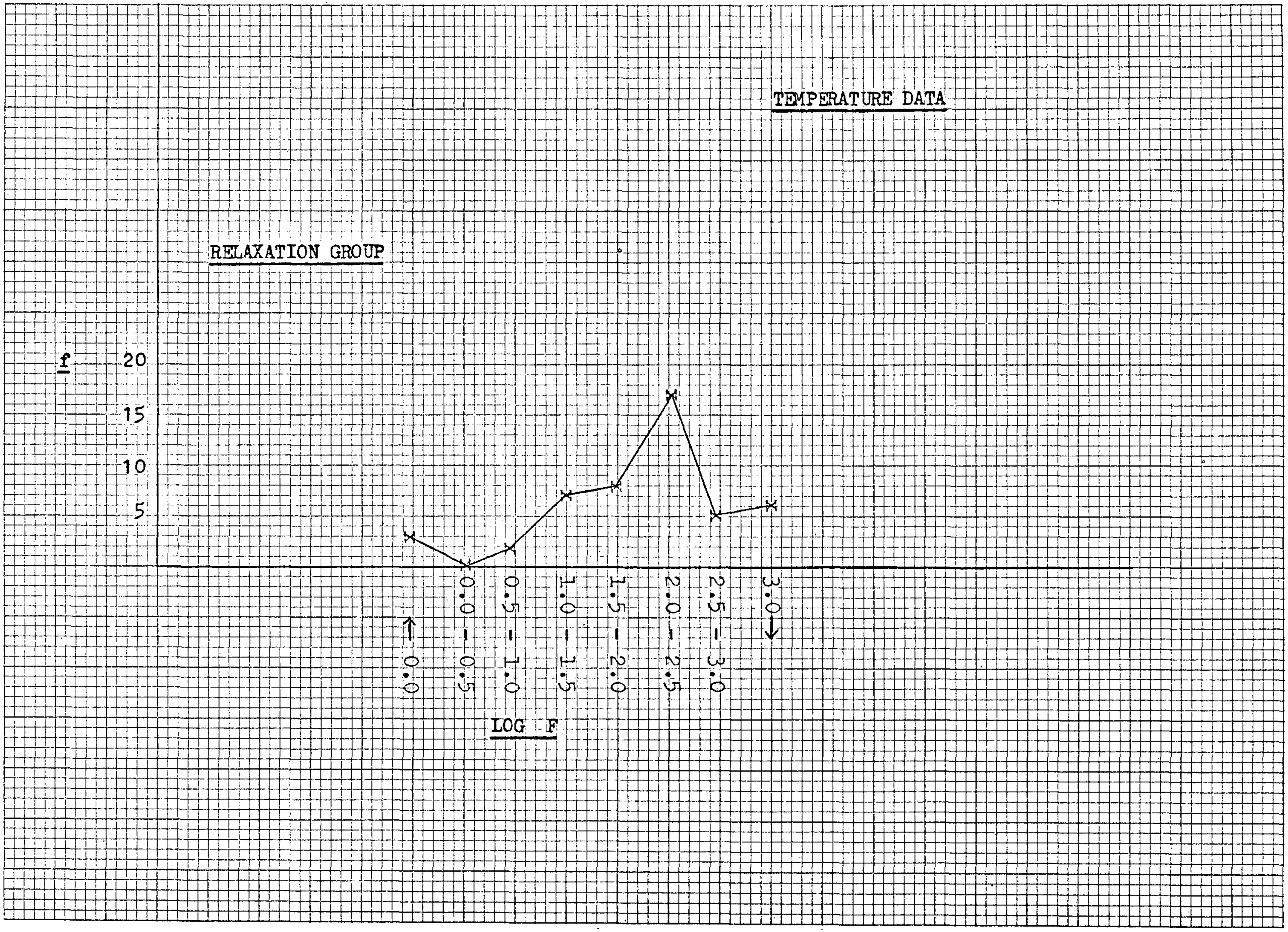
TRUE FEEDBACK GROUP




PULSE DATA
RELAXATION GROUP
f
20
15
10
5
LOG F
3.0→
2.5 - 3.0
2.0 - 2.5
1.5 - 2.0
1.0 - 1.5
0.5 - 1.0
0.0 - 0.5
← 0.0


TEMPERATURE DATA
FALSE FEEDBACK GROUP
f
20
15
10
5
LOG F
3.0→
2.5 - 3.0
2.0 - 2.5
1.5 - 2.0
1.0 - 1.5
0.5 - 1.0
0.0 - 0.5
← 0.0


TRUE FEEDBACK GROUP
TEMPERATURE DATA
f
20
15
10
5
← 0.0
0.0 - 0.5
0.5 - 1.5
1.0 - 1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 →
LOG F


TEMPERATURE DATA
RELAXATION GROUP
f
20
15
10
5
← 0.0
0.0 – 0.5
0.5 – 1.0
1.0 – 1.5
1.5 – 2.0
2.0 – 2.5
2.5 – 3.0
3.0 →
LOG F